

AD-A073 419

CIVIL ENGINEERING LAB (NAVY) PORT HUENEME CA

F/6 5/1

ENERGY MONITORING AND CONTROL SYSTEM (EMCS). ECONOMIC ANALYSIS --ETC(U)
FEB 79

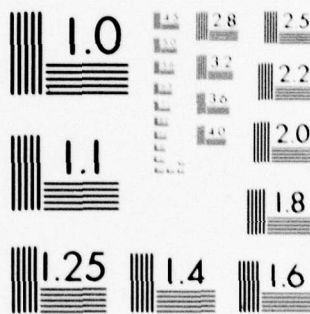
UNCLASSIFIED

NL

1 OF 2

AD
A073419





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

① LEVEL II

ADA073419



PO NO. 78 MR 423

62765N

CIVIL ENGINEERING LABORATORY

391111

NAVAL CONSTRUCTION BATTALION CENTER
Port Hueneme, California 93043

TITLE: 6

ENERGY MONITORING AND CONTROL SYSTEM (EMCS),
ECONOMIC ANALYSIS GUIDELINE
FOR
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP)
AND
ENERGY TECHNOLOGY APPLICATIONS PROGRAM (ETAP)

12 136 p.

CORPORATE AUTHOR:

NEWCOMB & BOYD CONSULTING ENGINEERS
ATLANTA, GEORGIA

DATE: 11

FEB 1979

16 F57572

SPONSOR:

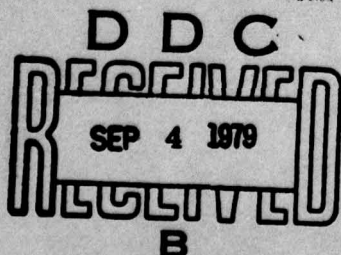
NAVAL FACILITIES ENGINEERING COMMAND

PROGRAM NOS. 17

ZF57571

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited



79 07 16 109

392 111

all

DDC FILE COPY

Page 38.

Replace Paragraph 2 with:

"The cost of an EMCS project is determined by the system/ functions that individually meet the criteria of the funding program. This minimizes the potential of future project incrementation. A prioritization based on the annual energy savings to investment ratio for each of these system/functions should be performed. This prioritization can be useful in some cases where cost overruns are later experienced and decisions are required on accomplishing the most beneficial scope of the project."

Paragraph 3

Change introductory sentence to:

"The basic steps for the prioritization of an EMCS project are:"

Change items 4 & 5 to:

"4. Calculate the savings to investment ratio and the annual energy savings to investment ratio (E/C) for each alternative."

"5. For those alternatives that meet criteria, rank in descending order the alternatives by the annual energy savings to investment ratio (E/C)."

Delete items 6 & 7

Page 95.

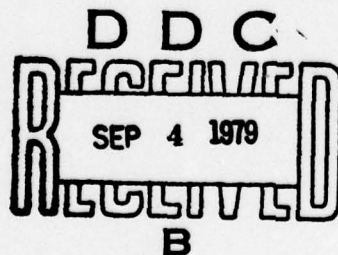
The cutoff line shown is in error. The project cost is determined by the amount of justifiable scope. If Building 200 meets criteria, it would be included in the project.

CONTENTS

1.0 SUMMARY	1
2.0 EMCS OVERVIEW	2
3.0 ANALYSIS CONCEPTS	7
4.0 FIELD INVESTIGATION	8
5.0 SAVINGS ANALYSIS	13
6.0 COST ANALYSIS	17
7.0 PRIORITIZATION ANALYSIS	38
8.0 OVERALL ECONOMIC ANALYSIS	40
9.0 SAMPLE NAVAL BASE	44

APPENDIX

A. EMCS FUNCTION DESCRIPTIONS	99
B. TYPICAL SYSTEM SCHEMATICS	104
C. SAVINGS ANALYSIS DISCUSSION	124
D. ANALYSIS FORMS	129



ACCESSION for		
NTIS	White Section	<input checked="" type="checkbox"/>
DDC	Buff Section	<input type="checkbox"/>
UNANNOUNCED		<input type="checkbox"/>
JUSTIFICATION		
PER LETTER		
BY		
DISTRIBUTION/AVAILABILITY CODES		
Dist.	AVAIL.	and/or SPECIAL
A		

DISTRIBUTION STATEMENT A
 Approved for public release;
 Distribution Unlimited

1.0 SUMMARY

This document is prepared in accordance with Contract ~~N68305-8156~~-0007 from the Civil Engineering Laboratory NCBC, Port Hueneme, California 93043, under the supervision of Mr. Dale H. Johnson, Code L26, AV360-5795/4661, FTS 799-5795/4661, AC(805) 982-5795/4661.

This document establishes methods for performing economic analysis of Energy Monitoring and Control Systems (EMCS) for Energy Conservation Investment Program (ECIP) and Energy Technology Applications Program (ETAP) funding.

Analysis for ETAP funded projects are similar to that of ECIP with the following exceptions:

1. In the economic analysis summary when determining energy savings vs. investment (MBTU/\$K) (line 9) and simple payback, (line 10), design costs not yet obligated (1b) must be added to line (1a) for ETAP funded projects.
2. ETAP funding is for energy conservation projects of \$5K-\$100K range. Projects will be prioritized by energy saved/investment ratio.
3. ECIP funding is for energy conservation projects of greater than \$100K range.

Various common EMCS functions along with typical energy consuming systems to which they are applied are described. Procedures for estimating potential energy and cost savings from the application of each EMCS function are included. Data for use in preparing EMCS cost estimates has been obtained through a survey of EMCS manufacturers and is tabulated. Methods for determining the best alternative uses of an EMCS when funding levels are fixed are presented. Forms and requirements specifically related to the completion of an "ECIP Economic Analysis Summary" are included.

General description and derivation of the methods established are included in Sections 2.0 through 8.0 and in the APPENDIX of this report. Section 9.0 provides a step-by-step example of the use of these procedures.

2.0 EMCS OVERVIEW

The purpose of this report is to provide guidelines for economic analysis of Energy Monitoring and Control Systems (EMCS) as they apply to basewide Navy installations. A method is presented for completion of an Energy Conservation Investment Program (ECIP) Economic Analysis Summary. This summary may also be used for Energy Technology Applications Program (ETAP) projects.

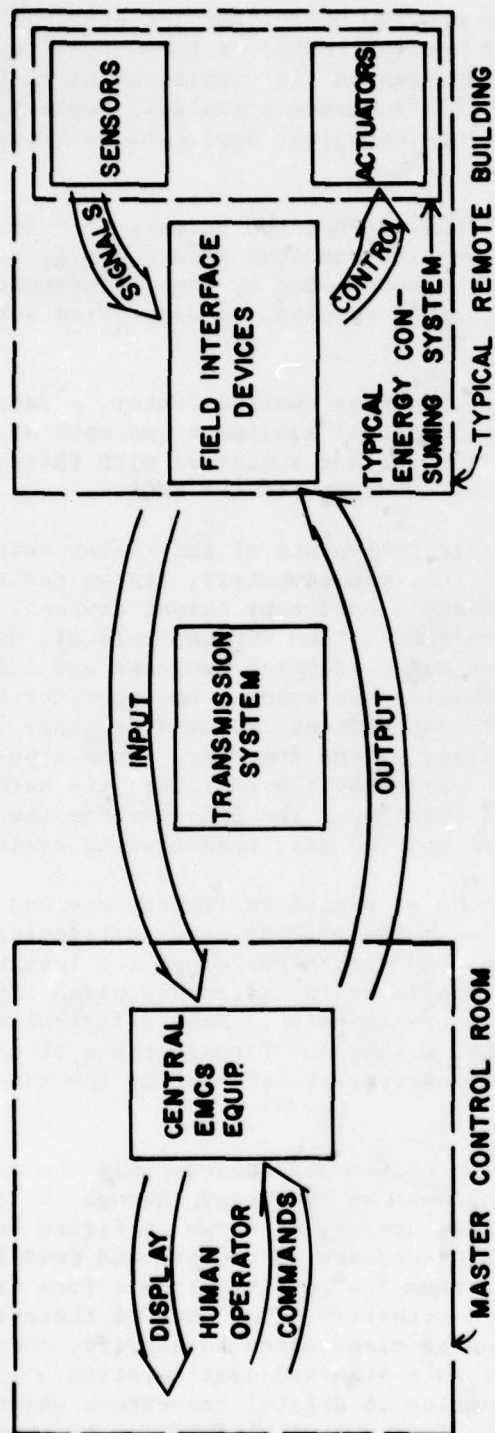
Based on the current Navy design philosophy, the primary purpose of an EMCS is to effect reduced energy consumption and thus reduce energy related operating expenses. This goal is accomplished by exercising control over energy consuming mechanical/electrical systems. A simplified schematic of an EMCS is illustrated in Figure No. 1.

Generally an EMCS will consist of a master control center, a data transmission system between the central control equipment and each of the buildings connected to the EMCS, and sensors and actuators with their related equipment located in each building connected to the EMCS.

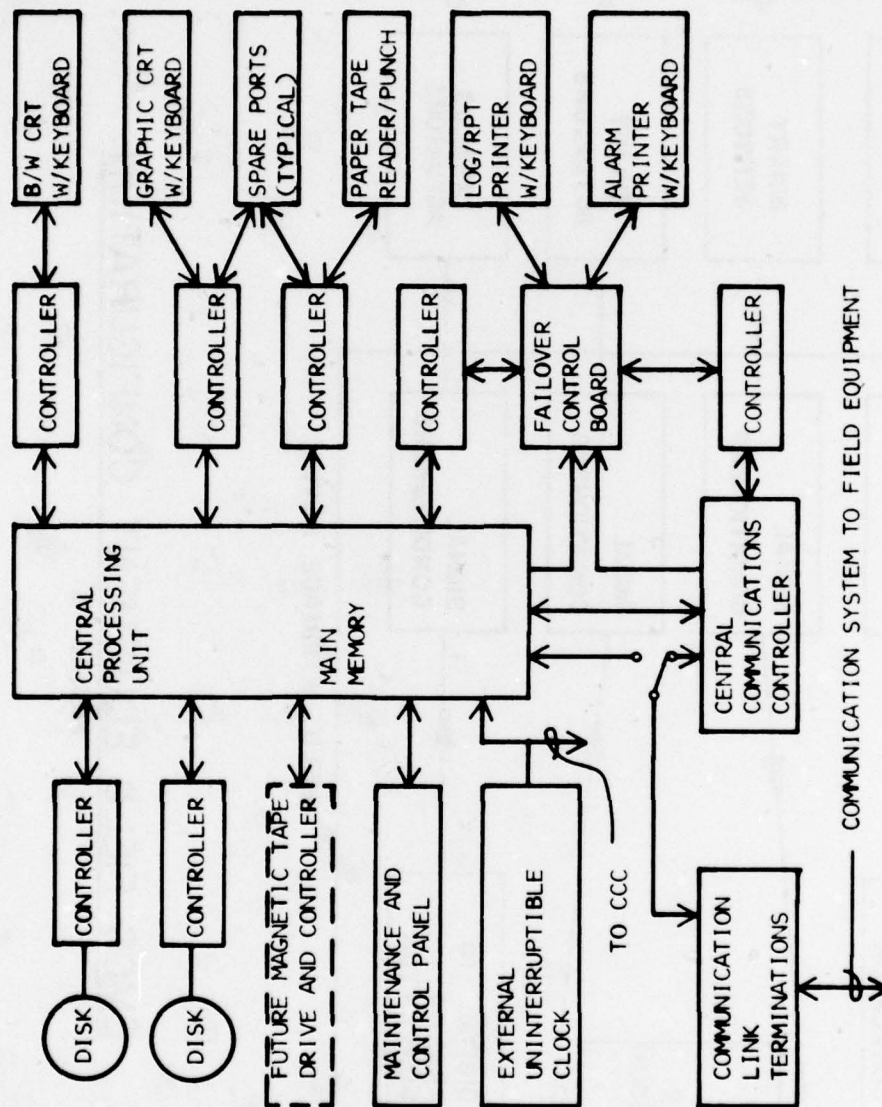
As shown in Figure No. 2, the basic components of the master control center includes a Central Control Unit (CCU, minicomputer), system control consoles (CRT's), mass storage devices (disks), hard copy output devices, and a Central Communications Controller (CCC). The CCU controls all master control center devices, processes data, executes programs and interprets commands. The system control consoles are used by the operator to communicate with the EMCS. The mass storage devices are used to store information that is not currently being utilized by the computer. When a permanent copy of an alarm or a report is desired by the operator, the hard copy output devices are used for this function. The CCC provides the interface between the master control center and the data transmission system.

The data transmission system may be of varied configurations and consist of several different components. Among the methods used to transfer data between the master control center and remote buildings are leased or government furnished telephone lines, specially installed dedicated signal lines, radio transmission, and microwave transmission. Many different methods and design philosophies are associated with each of these types of data transfer. At this time, none of the EMCS manufacturers use exactly the same transmission methods and protocols.

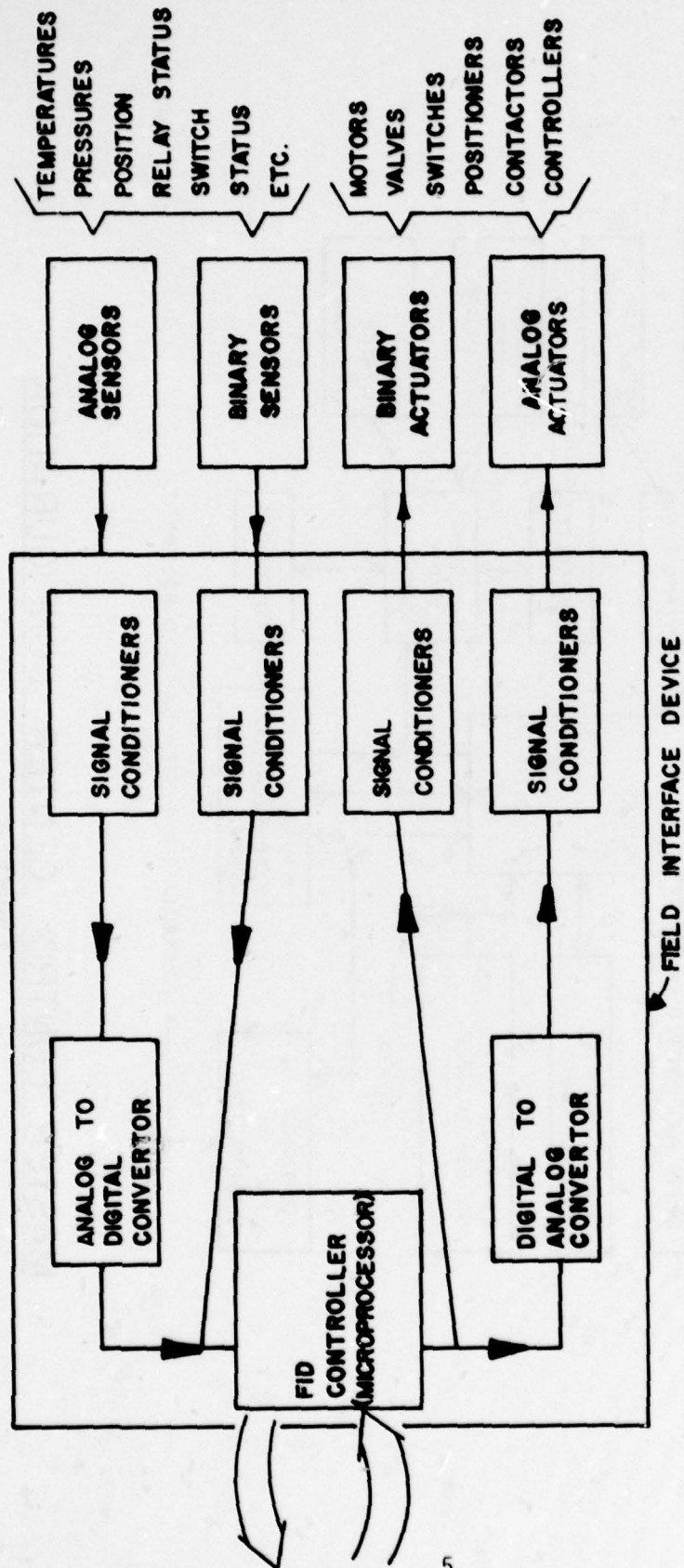
To interface with the transmission system and subsequently the master control center, a remote building must be connected through at least one field interface device (FID). This device, as shown in Figure No. 3, includes the electronic equipment necessary to receive and send information over the specific transmission system, to receive signals from field sensors, and to transmit signals to field actuators. For each of these functions, the FID contains signal conditioning electronics to amplify, convert, or otherwise modify field signals into a standard configuration. The field interface device also contains analog to digital convertors which convert analog signals from field sensors into a digital form for transmission to the central control center. Digital to analog converters convert digital signals from the control center to analog signals for control of actuators. Typically, sensors connected to the field interface device measure temper-



EMCS BLOCK DIAGRAM
FIGURE 1



MASTER CONTROL CENTER CONFIGURATION
FIGURE 2



EMCS FIELD EQUIPMENT CONFIGURATION

FIGURE 3

atures, pressures, position of various mechanical devices, relay status, switch status, etc. The actuators discussed consist of a variety of devices including motors, valves, switches, positioners, relays, controllers, etc.

Recent industry trends are toward the use of "smart" field interface devices. In these systems the field interface device contains a microcomputer system capable of handling and storing data from sensors, and transmitting data to the central control center by exception. These FIDs are designed so they can continue operation even when communication with the central control center is interrupted. They are smart enough to do time clock type functions and some system optimization.

This discussion constitutes a simplified and generalized definition of an energy monitoring and control system. There are as many different devices and configurations for each of the components defined as there are EMCS manufacturers.

3.0 ANALYSIS CONCEPTS

The basic steps required in performing an EMCS analysis are:

1. Field Investigation
2. Savings Analysis
3. Cost Analysis
4. Prioritization Analysis
5. Overall Economic Analysis

Field investigation determines what energy consuming systems are present which an EMCS may control, and what EMCS functions may be performed on those systems.

The savings analysis determines the potential energy and cost savings from EMCS installation.

The cost analysis estimates investment required to install the EMCS.

The prioritization analysis determines which alternatives should be included in the project in order to provide the maximum savings for a given investment.

Once the alternatives to be included in the project are determined, an overall economic analysis of the EMCS may be performed.

4.0 FIELD INVESTIGATION

The primary purpose of the field investigation phase of the analysis is to determine what energy consuming systems are present which may be controlled by the proposed EMCS. What EMCS functions may be performed on each of the systems must also be determined. A brief description of common EMCS functions is included in the APPENDIX. Also included in the APPENDIX are schematics of typical energy consuming systems which may be controlled by an EMCS.

In order to perform an EMCS analysis, pertinent information on the site for which the EMCS is proposed must be gathered. The following information is generally required:

1. Base map showing facility numbers and general layout of the Base.
2. Utility maps showing Base electrical distribution, water, sewer, and communications systems.
3. Facility listings indicating:
 - a. Facility ID Number
 - b. Facility Name/Description
 - c. Facility floor area, square feet
4. Utility cost data including rate structures or current prices, and copies of billings over the last year. Estimated local escalation rates should be provided if available.
5. Information from the Base Communications/Telephone Office on the quality, availability, and cost of utilizing Base telephone lines for data transmission.
6. Shop drawings, specifications, or other information on any existing EMCS or similar central control systems.
7. Information on any past, current, or future energy conservation projects such as control upgrades, insulation projects, etc.
8. Plans for future additions to buildings or new building which might be connected to or affect the EMCS. Also, plans for demolition of existing buildings.
9. Listings of critical facilities which should be connected to the EMCS for monitoring purposes (computer rooms, flight simulators, etc.).
10. "As-built" mechanical, electrical and control drawings of each building being considered for connection to the EMCS.
11. Schedules of occupancy and usage for people, lights, and equipment for each building.

12. Any available small scale plans of buildings under consideration for EMCS connection.

The "as-built" mechanical drawings are a necessity for the efficient use of field survey time. Without them, much time may be wasted in trying to track down every mechanical room in a building, particularly if the building is large and has been extensively remodeled. Because of the large number of systems and drawings on a military base, obtaining the required prints can be a problem. In general, if base personnel are simply asked to provide copies of all mechanical and electrical drawings for the buildings on the list, difficulties occur. Fulfilling such a request will require 500 to 2000 prints. Base Engineering records departments are not usually equipped to handle such a load in the time frame needed. Also, many of the drawings which would be provided by such a request are not needed for the EMCS design analysis. The best solution to this problem is for the EMCS design engineer to review the tracing files for the buildings in question. Only those tracings which are absolutely necessary for use in the EMCS field investigation should be selected for printing. Whatever approach is to be utilized, it must be clearly defined before the project is initiated and dates established by which drawings must be provided.

To perform detailed analysis of a proposed EMCS, schedules of occupancy and usage for people and equipment in the buildings being considered must be obtained. On some bases this information has been gathered for use in other projects and may be available through the Base Engineering Office. If not, it must be obtained. Several approaches may be used, including a telephone survey of custodians of each building, written memos to the users of each building, discussion with base maintenance personnel, or visits to each building to discuss schedules with the occupants.

On some bases, small scale plans of buildings may be available. These have usually been prepared for use in planning, office allocations, fire escape routes, or other purposes. These drawings are generally on 8-1/2" x 11" sheets at whatever scale is necessary to depict floor plans of the building. These drawings are extremely useful in the building by building survey for the identification and location of systems. If these are not available, full scale drawings are not as convenient for the field investigation but they can be used.

Once drawings are obtained, they are used to plan the survey work to be done during each site visit. Much time can be wasted without a definite plan of items to be accomplished during each day of the field investigation and adequate preparations to meet planned requirements.

The purpose of the field investigation is to determine which systems are to be considered for EMCS connection and to gather enough information on each system to allow analysis of that system. Once the design analysis is completed and the systems to be connected to the EMCS are identified, a detailed field inspection of each of those systems must be performed in the final design stage. This detailed survey must closely examine each system for sensor location, existing controls condition, EMCS interface to local controls, damper actions, etc. However, the field investigation required to perform the basic design analysis described in this report does not require this detailed hardware inspection. The field work for the design

analysis stage of the project is primarily concerned with identifying the type of system in question, its current operating hours, its required operating hours, the horsepower of motors in the system, and other data required for the analysis of savings which would result from EMCS control of that system.

The most efficient approach to the field investigation itself has been found to be the gathering of as much data as possible from drawings of each building and using the site survey to verify the data obtained from the drawings. One important aspect of this approach is the development of standard survey data sheets. These sheets provide a basis for the data gathering and should include blanks for all data pertinent to the analysis. Each engineer has a different approach to the survey data recording problem and whether one uses a separate form for each system type, a single standard form, a tabular approach, or some other method is not important as long as the data are recorded and easily referred to. An example of one type of field survey data sheet is included as Figures 4 and 5.

SURVEY AND BUILDING DESCRIPTION FORM

Building Number: _____ Usage: _____

Gross Area Sq. Ft.: _____ No. Floors: _____

Age of Building: _____ Type Construction: _____

Approx. Floor to Floor Height: _____

% Glass in Exterior Wall: _____

-11-

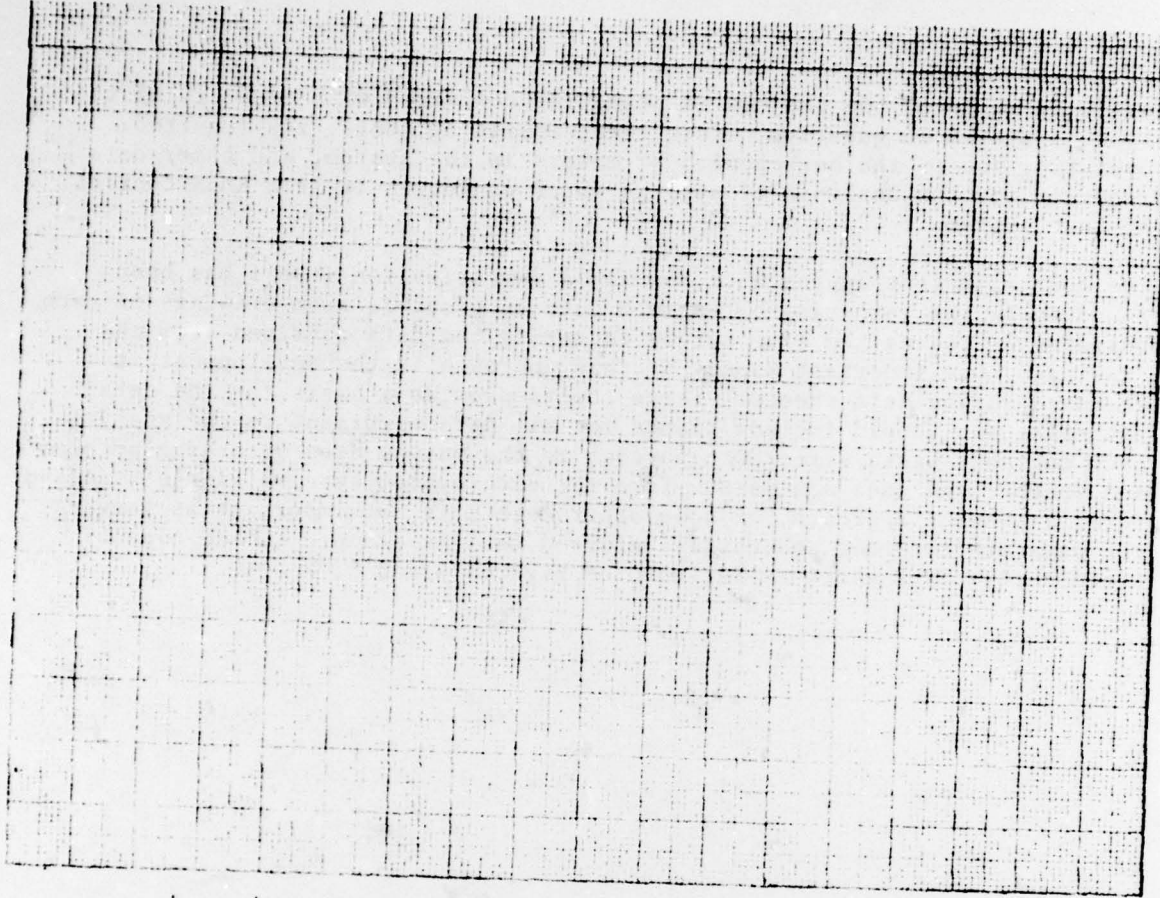
Glass Shading: External _____ Internal _____

"U" Factor: Roof _____ Wall _____ Glass _____

Critical Areas: _____

Notes: _____

FIGURE 4



PRIMARY SYSTEMS

Sys #

Type: (HW) (STM)
Boiler (A/C) (W/C)
Chiller (A/C) (W/C)
DX Unit (A/C) (W/C)
Central (STM) (CHW)
Other:

Capacity: BTU/HR.
Pump HP:
Pump HP:
Comp HP:
Fan HP:
Other HP:

Operation (Annual)
Year Round
Summer Only
Winter Only
Other:

Operation (Daily)
1 Shift
2 Shift
3 Shift
Other:

Existing Controls:
Time Clock
O.A. Reset
Other:

Notes:

Sys #

Type: (HW) (STM)
Boiler (A/C) (W/C)
Chiller (A/C) (W/C)
DX Unit (A/C) (W/C)
Central (STM) (CHW)
Other:

Capacity: BTU/HR.
Pump HP:
Pump HP:
Comp HP:
Fan HP:
Other HP:

Operation (Annual)
Year Round
Summer Only
Winter Only
Other:

Operation (Daily)
1 Shift
2 Shift
3 Shift
Other:

Existing Controls:
Time Clock
O.A. Reset
Other:

Notes:

Sys #

Type: (HW) (STM)
Boiler (A/C) (W/C)
Chiller (A/C) (W/C)
DX Unit (A/C) (W/C)
Central (STM) (CHW)
Other:

Capacity: BTU/HR.
Pump HP:
Pump HP:
Comp HP:
Fan HP:
Other HP:

Operation (Annual)
Year Round
Summer Only
Winter Only
Other:

Operation (Daily)
1 Shift
2 Shift
3 Shift
Other:

Existing Controls:
Time Clock
O.A. Reset
Other:

Notes:

SECONDARY SYSTEMS

Sys #

Type: (SZ) (TR)
AHU (HW) (HU)
Unit Htr. (FU)
Fan Coil (2) (4) pipe
Convactor (HW) (STM)
Other:

CFM:
No. Zones:
Fan HP:
Capacity: BTU/HR.
Pump HP:
20A:
Comp. HP:
Cond Fan HP:

Operation (Daily)
1 Shift
2 Shift
3 Shift
Other:

Existing Controls:
Time Clock
Economizer
Deck Reset
Other:

Notes:

Sys #

Type: (SZ) (TR)
AHU (HW) (HU)
Unit Htr. (FU)
Fan Coil (2) (4) pipe
Convactor (HW) (STM)
Other:

CFM:
No. Zones:
Fan HP:
Capacity: BTU/HR.
Pump HP:
20A:
Comp. HP:
Cond Fan HP:

Operation (Daily)
1 Shift
2 Shift
3 Shift
Other:

Existing Controls:
Time Clock
Economizer
Deck Reset
Other:

Notes:

5.0 SAVINGS ANALYSIS

Savings resulting from installation of an EMCS may be simply stated as:

$$S = RC_1 - RC_2$$

where:

S = net savings

RC_1 = resources (energy, demand, or manpower) consumed prior to EMCS installation

RC_2 = resources (energy, demand, or manpower) consumed after EMCS installation.

Historical data currently does not exist in sufficient detail to allow direct estimation of either RC_1 or RC_2 . RC_1 is generally available only on a basewide basis. Sufficient data from existing EMCS installations has not been collected to allow estimation of RC_2 on that basis. Since historical data is not available, engineering estimates based on theoretical equations, accepted engineering practice, and related experience must be used.

The logical basis of EMCS savings calculation is on a function-by-function basis.

Where resource consumption is simply a function of equipment running time or size, straightforward equations may be derived. The equations are suitable for manual calculations. Where resource consumption is a function of more complex variables (such as weather conditions, building occupancy, system type, etc.) more involved analysis is required. This analysis may require extensive manual or computerized calculations to reasonably simulate the conditions. The engineer must use experience and judgement in selecting methods appropriate for each situation.

Because savings resulting from performing several functions on the same energy consuming system are interrelated, false duplication of savings in the analysis must be avoided. This is done by performing calculations in a hierarchical fashion. Generally, functions performed on a system must be analyzed one after the other, with each analysis based on the existence of the previous functions. Examples of such an approach would be found in the estimation of savings resulting from EMCS control of an air handling unit. If, prior to installation of the EMCS, the air handler runs 24 hours per day, even though it is required to operate only 12 hours per day, an obvious EMCS function to perform is TIME SCHEDULED OPERATION. Another potential EMCS function might be ENTHALPY ECONOMIZER. The economizer operation energy savings are dependent on the number of hours per day the air handler operates. Economizer savings calculations must be based on a 12 hour per day operation since that is the schedule on which the system will operate following EMCS installation. In general, those functions which provide the maximum savings should be analyzed first with other function's savings calculated based on the existence of those maximum savings functions.

Methods of calculating savings resulting from each typical function have been examined and a summary of the resultant equations are as follows (see APPENDIX C for description of the equations and a discussion of simulation requirements where such is indicated):

Symbols - The following symbols are used in the savings calculation equations:

= control efficiency factor

= fraction of an hour which system may be cycled off during critical electrical demand situations.

FLH = equivalent full load hours, annually

H = number of hours of required operation per year

HS = number of hours in summer where system may be shut off because the outside temperature is below a limit.

HW = number of hours in winter where system may be shut off because the outside temperature is above a limit.

I = maximum heat transfer capacity of device in THERMS.

KW/HP = conversion at 0.746 KW/HP

L = load factor

M = number of months during which load operates only applicable when demand is calculated monthly (no ratchet clause) and demand unit cost is in monthly, not annual, units.

O = fraction of an hour which system may be cycled off for consumption reduction.

OD = number of days of required operation per year.

PECD = percent energy consumption decrease, annually (expressed in decimal, i.e. 1% = .01)

PEI = percent efficiency increase per °F increase/decrease in CHW/CDW temperature (expressed in decimal, i.e., 1% = .01)

SKW = Annual kilowatt demand savings

SKWH = Annual kilowatt hour savings

STHERMS = Annual therms heating savings

Methods of calculating savings resulting from each typical function have been examined and a summary of the resultant equations are as follows (see APPENDIX C for description of the equations and a discussion of simulation requirements where such is indicated):

Symbols - The following symbols are used in the savings calculation equations:

C	=	control efficiency factor
D	=	fraction of an hour which system may be cycled off during critical electrical demand situations.
EFLH	=	equivalent full load hours, annually
H	=	number of hours of required operation per year
HS	=	number of hours in summer where system may be shut off because the outside temperature is below a limit.
HW	=	number of hours in winter where system may be shut off because the outside temperature is above a limit.
I	=	maximum heat transfer capacity of device in THERMS.
KW/HP	=	conversion at 0.746 KW/HP
L	=	load factor
M	=	number of months during which load operates only applicable when demand is calculated monthly (no ratchet clause) and demand unit cost is in monthly, not annual, units.
O	=	fraction of an hour which system may be cycled off for consumption reduction.
OD	=	number of days of required operation per year.
PECD	=	percent energy consumption decrease, annually (expressed in decimal, i.e. 1% = .01)
PEI	=	percent efficiency increase per °F increase/decrease in CHW/CDW temperature (expressed in decimal, i.e., 1% = .01)
SKW	=	Annual kilowatt demand savings
SKWH	=	Annual kilowatt hour savings
STHERMS	=	Annual therms heating savings

Time Scheduled Operation

- ° Cooling Savings - Simulation
- ° Heating Savings - Simulation
- ° Auxiliary Savings (fans, pumps, constant running apparatus) -

$$SKWH = HP \times L \times KW/HP \times (8760-H) \times C$$

HP = total nameplate HP of constant loads.

Duty Cycling

- ° Heating and Cooling Savings - Assume None
- ° Auxiliary Savings (fans, pumps, constant running motors) -

$$SKWH = HP \times L \times O \times H \times KW/HP$$

HP = total nameplate HP of constant loads.

Demand Limiting

- ° $SKW = HP \times L \times KW/HP \times D \times M$

HP = total electrical load of system (fans, pumps, compressors, etc.)

Start/Stop Optimization

- ° Cooling Savings - Assume None
- ° Heating Savings - Assume None
- ° Auxiliary Savings -

$$SKWH = HP \times L \times KW/HP \times T \times OD$$

Outside Air Limit Shutoff

- ° Auxiliary Savings (fans, pumps, etc.) -

$$SKWH = HP \times L \times KW/HP \times (HS + HW)$$

HP = nameplate HP of constant loads.

Maintenance Run Time

- ° Savings - estimate manhours based on current maintenance practices (i.e. roving patrols, preventive maintenance schedules, etc.)

Enthalpy Economizer

- ° Cooling Savings - Simulation
- ° Heating Savings - None

Hot/Cold Deck Reset

- ° Cooling Savings - Simulation
- ° Heating Savings - Simulation

Chilled Water Reset

- ° Cooling Savings -

$$SKWH = \text{Tons} \times EFLH \times 1 \text{ KWH/ton-hr.} \times PEI \times (^\circ\text{F CHW Increase})$$

Condenser Water Reset

- ° Cooling Savings -

$$SKWH = \text{Tons} \times EFLH \times 1 \text{ KWH/ton-hr.} \times PEI \times (^\circ\text{F CW Decrease})$$

Outside Air Schedule Reset

- ° Heating Savings -

$$STHERMS = EFLH \times PECD \times I$$

Safety Alarms

- ° Savings - Estimate Manhours

Intercoms

- ° Savings - Estimate Manhours

6.0 COST ANALYSIS

The accurate analysis of an EMCS requires accurate and reliable cost estimating data. This is extremely important because potential savings alone do not determine whether a particular function should be connected to the EMCS. The cost of that function is equally important in determining whether or not it should be connected. Cost estimating is of additional importance because cost for a particular EMCS function is relatively constant, irrespective of the size of the system being controlled. It essentially costs the same to start and stop a ten horsepower fan as it does to start and stop a one horsepower fan. However, the difference in potential energy savings is tenfold.

Several items complicate the cost estimating analysis. The first and probably most important complication is the fact that no two manufacturers' EMC systems are identical. Every manufacturer takes a different approach to performing each EMCS function. For example, because of a particular configuration, one manufacturer may be able to provide a status feedback for a piece of equipment being started and stopped by the EMCS for a very small cost, whereas a different manufacturer with a different configuration might actually double the cost of simply providing start-stop capability, if status feedback is required. Another difficulty arises from the reliability of budget estimates received from manufacturers' sales representatives. For obvious reasons, these representatives generally are very guarded about revealing detailed or exact cost information. They generally prefer only to give rough budget estimates based on the total number of points in a system. This type of information is not adequate for the detailed analysis of an EMCS. Each component cost of the EMC system must be broken down separately to perform comparative analysis. Obtaining this type of information has been difficult. However, several manufacturers were willing to provide the information which has been used in this study.

In order to determine an optimum EMCS configuration, each cost component of the system must be analyzed. The five main cost components of an EMCS are 1) general cost, 2) central control center cost, 3) transmission system cost, 4) facility connection cost, 5) sensor/actuator cost.

General cost consists of the following components:

- a. Estimation
- b. System engineering
- c. Shop drawing preparation
- d. System testing and debugging
- e. Training
- f. Maintenance contract

All of these costs involve a considerable amount of overhead time, thus making them only slightly dependent on the number of facilities and sensor/actuators connected to the EMCS.

Operations and Maintenance cost for the EMCS deserves special note. In addition to the maintenance contract cost, government operators must also be employed to properly utilize the system. Traditionally a total annual operations and maintenance cost of 10% of the original system cost is

included in economic analysis of EMCS. If more exact figures are available (such as staffing requirements studies) then those should be used in lieu of the 10% figure.

The central control center consists of the following main components:

- a. Central processing unit hardware
- b. Peripheral hardware and associated software drivers
- c. Operating system software
- d. EMCS command software
- e. EMCS applications software
- f. Communications hardware
- g. Communications software

The cost of these components is relatively constant, irregardless of the number of facilities or sensor/actuators that are connected to the system.

- a. Overhead transmission cable
- b. Underground transmission cable
- c. Telephone modems (Modulator-demodulator)

This cost is basically a function of the number and location of facilities connected to the EMCS.

Facility connection costs are those fixed costs associated with connecting a facility to the EMCS which are independent of the number of sensors/-actuators that are installed within that facility. Facility connection cost is the fixed cost which would be incurred to connect a facility to the EMCS even though that facility only required a single EMCS sensor. The components of facility connection costs are:

- a. A field interface device, along with its power supply and installation
- b. The transmission line to the building in question, if a dedicated contractor installed transmission system is being utilized
- c. Telephone lines and modems from the building in question back to central console location if a telephone transmission system is used

The facility connection costs listed above are dependent on the number of facilities connected to the EMCS and not on the number of sensor/actuators.

The sensor/actuator cost is the cost to add a sensor/actuator to the EMCS, assuming a field interface device to which this point will be connected is already available in the building. Cost components associated with each sensor/actuator are:

- a. A signal conditioning device usually in the form of an integrated circuit card which plugs into an appropriate slot in the field interface device

- b. Wiring from the field interface device to the sensor/actuator
- c. The sensor/actuator itself
- d. The installation and interface of the sensor/actuator with the existing local control system
- e. Local controls which must be replaced, repaired, or added
- f. Miscellaneous new equipment (dampers, ductwork, thermometer wells, Venturi tubes, insulation, auxiliary starter contacts, etc.)
- g. Definition and entry of each sensor/controller into the central control center

The total sensor/actuator cost is a function of the number of points connected to the EMCS and generally not related to the number of different facilities in which those points occur.

Several manufacturers were contacted and presented with a list of questions designed to obtain specific cost estimates for the components listed above. The data supplied as a result of this request is listed in Table 1 thru Table 5. Spaces left blank indicate that information was not supplied for that item by that manufacturer. Some manufacturers requested that their prices not be openly presented for protection from their competition; therefore, none of the manufacturers names have been listed. It should be pointed out that both conventional controls manufacturers and the smaller "systems house" manufacturers are included in those listed. The figures included here were obtained during November, 1978.

TABLE 1
CENTRAL SYSTEM EQUIPMENT
MANUFACTURERS DATA

	A	B	C	D	E	F	G	VALUE USED IN STUDY
1. CENTRAL CONTROL UNIT (CCU)	:: (1) 8,650 :: (2) 10,650	(42) 94,000	:: (3) 13,200 :: (4) 19,400	(5) 21,800	:: (6) 8,650 :: (7) 10,650	(8) 19,000 (9) 24,500 (10) 36,000	:: (13) 16,000	\$25,000
2. CENTRAL COMMUNICATION CONTROLLER (CCC)	:: (24) 32,000			(11) 23,000		(12) 17,000	(14) 28,000	\$25,000
3. AUXILIARY POWER SUPPLY			(16) 7,000					
4. EXTERNAL UNINTER- RUPTABLE CLOCK			(53) 1,625					\$ 1,625
5. DISK STORAGE SYSTEM	:: (15) 22,500	:: (43) 3,940	:: (17) 26,700	:: (20) 10,200	:: (20) 22,500	(18) 22,500	:: (21) 10,200	\$20,000
6. PRINTER	:: (23) 2,850	(44) 4,700	(26) 1,700	(25) 9,330	(27) 2,850		:: (22) 3,000	\$ 4,000
7. CRT COLOR	:: (32) 2,685	(45) 15,900	(33) 2,585	(34) 7,500	:: (38) 2,685	:: (36) 2,360	:: (37) 2,780	\$ 8,000
8. CRT B&W	:: (28) 2,650	(46) 4,300	(30) 2,000	(38) 3,200	:: (29) 2,650	:: (31) 1,935	(54) 4,300	\$ 3,000
9. PAPER TAPE READER/ PUNCH	:: (39) 2,160	(47) 8,500	:: (51) 8,300			:: (40) 4,600		\$ 5,000
10. FAILOVER CONTROL BOARD		(49) 1,800						\$ 1,800
11. INTERCOM		(30) MASTER 2,700 REMOTE 160						
12. MAGNETIC TAPE UNIT		:: (48) 13,280	:: (52) 9,500			:: (41) 13,500		\$13,000

:: INDICATES PRICES OBTAINED FROM OEM VENDORS. THE PRESENT TREND INDICATES THE EMCS CONTRACTORS USE A 100% MARK UP ON THE OEM ITEMS.

TABLE 1. FOOTNOTES
CENTRAL SYSTEM EQUIPMENT

- (1) BASED ON INFORMATION SUPPLIED BY MODULAR COMPUTER SYSTEMS FOR MODCOMP 7810 COMPUTER WITH 64KB MEMORY AND CABINET.
- (2) BASED ON INFORMATION SUPPLIED BY MODULAR COMPUTER SYSTEMS FOR MODCOMP 7810 COMPUTER WITH 128KB MEMORY AND CABINET.
- (3) BASED ON INFORMATION SUPPLIED BY HEWLETT PACKARD ON 21MX-E PROCESSOR WITH TIME BASE GENERATOR, CHANNEL CONTROLLER, MEMORY PROTECT, POWER FAIL OPTION, 64KB MEMORY AND A CABINET.
- (4) SAME AS FOOTNOTE 3 BUT WITH 218KB MEMORY.
- (5) BASED ON EMCS VENDOR'S ESTIMATE USING DIGITAL'S PDP 11/34 CPU WITH 64KB MEMORY IN 10-1/2" CABINET.
- (6) BASED ON INFORMATION SUPPLIED BY MODULAR COMPUTER SYSTEM FOR MODCOMP 7810 COMPUTER WITH 64KB MEMORY AND CABINET.
- (7) BASED ON INFORMATION SUPPLIED BY MODULAR COMPUTER SYSTEM FOR MODCOMP 7810 COMPUTER WITH 128KB MEMORY AND CABINET.
- (8) BASED ON INFORMATION SUPPLIED BY THE EMCS VENDOR USING A INTERDATA 816E COMPUTER WITH 64KB CORE MEMORY AND FLOATING POINT PROCESSOR.
- (9) BASED ON INFORMATION SUPPLIED BY THE EMCS VENDOR USING A INTERDATA 816E COMPUTER WITH 128KB CORE MEMORY AND FLOATING POINT PROCESSOR.
- (10) BASED ON INFORMATION SUPPLIED BY THE EMCS VENDOR USING A INTERDATA 816E COMPUTER WITH 256 CORE MEMORY AND FLOATING POINT PROCESSOR.
- (11) BASED ON INFORMATION SUPPLIED BY THE EMCS VENDOR THE CCC WOULD BE IMPLEMENTED USING A PDP 11/34 COMPUTER WITH 64KB MEMORY. THIS APPROACH WOULD SUGGEST THE USE OF THE DMC-11 FOR COMMUNICATION BETWEEN THE CCU AND CCC AND A DZ-11 TO SERVE AS THE CLT.
- (12) BASED ON INFORMATION SUPPLIED BY EMCS VENDOR, THE CCC WOULD BE IMPLEMENTED USING THE MULTIPLE MICRO PROCESSORS APPROACH.
- (13) BASED ON INFORMATION SUPPLIED BY DIGITAL FOR THE PDP11/34 CPU WITH 64K MEMORY IN A 10-1/2" CABINET.
- (14) BASED ON INFORMATION SUPPLIED BY THE EMCS VENDOR THE CCC WILL BE IMPLEMENTED USING A PACKAGED PDP11/34 WITH A DEDICATED DISK AND ONE OR MORE DZ-11'S.
- (15) BASED ON INFORMATION SUPPLIED BY MODULAR COMPUTER SYSTEM FOR A 10 MB DISK SYSTEM (L1136) USING TWO 5 MB DISK DRIVES WITH TWO CONTROLLER (4123) AND A SWITCH OVER CONTROL BOX (4906).
- (16) BASED ON ESTIMATE SUPPLIED BY EMCS VENDOR FOR U.P.S.

- (17) BASED ON INFORMATION SUPPLIED BY HEWLETT PACKARD FOR A 20 MB DISK DRIVES USING TWO 7906, 10 MB DISK UNITS, A 13175A INTERFACE AND A 13178B INTERFACE WITH CABLE.
- (18) BASED ON ESTIMATE SUPPLIED BY EMCS VENDOR.
- (19) BASED ON INFORMATION SUPPLIED BY MODULAR COMPUTER SYSTEM FOR A 10 MB DISK SYSTEM USING TWO 5 MB DISK UNITS (4136) WITH TWO CONTROLLERS (4136) AND A SWITCH OVER CONTROL BOX (L1906).
- (20) BASED ON DIGITAL'S RL01 SERIES OF DISK DRIVE SYSTEM. TWO RL01'S (5.2 MB EACH) CONTROLLED BY TWO RL-11 CONTROLLERS.
- (21) BASED ON DIGITAL'S RL01 SERIES OF DISK DRIVE SYSTEM. TWO RL01'S (5.2 MB EACH) CONTROLLED BY TWO RL-11 CONTROLLERS.
- (22) BASED ON DIGITAL'S DESK WRITER II (\$2,000) WITH DL-11 TERMINAL INTERFACE (\$770) AND CABLE.
- (23) BASED ON DIGITAL'S DESK WRITER II AND ONE HALF THE COST OF A MODCOMP ASYNCHRONOUS COMMUNICATION INTERFACE 4811 PLUS CABLE.
- (24) TO IMPLEMENT THE CCC, THE EMCS VENDOR WOULD LIKE TO USE A MODCOMP II AS THE COM CONTROLLER. THE COSTING FOR THIS APPROACH IS BASED UPON USING THE MODCOMP II 126/CP2, A PERIPHERAL CONTROLLER INTERFACE (4903), AND A UNIVERSAL COMMUNICATION CONTROLLER (1907). THIS APPROACH WOULD ALLOW COMMUNICATION OVER 138 LINES, AND IS EXPANDABLE TO 192 LINES OR 256 LINES.
- (25) BASED ON EMCS VENDOR'S ESTIMATE FOR THEIR CHOICE OF PRINTER. THE PRICING QUOTED REPRESENTS A FASTER PRINTER THAN REQUIRED BY THE GUIDE SPECS.
- (26) BASED ON THE EMCS VENDOR'S ESTIMATE USING A TELETYPE 43 (\$1000) WITH A ASYNCHRONOUS INTERFACE (\$700).
- (27) BASED ON DIGITAL'S DESK WRITER II AND ONE HALF THE COST OF MODCOMP ASYNCHRONOUS COMMUNICATION INTERFACE (4811) AND A CONNECTING CABLE.
- (28) BASED ON MODCOMP CONVERSATION CRT 4611 AND ONE HALF THE COST OF A ASYNCHRONOUS COMMUNICATION INTERFACE.
- (29) BASED ON MODCOMP CONVERSATIONAL CRT 4611 AND ONE HALF THE COST OF A ASYNCHRONOUS COMMUNICATION INTERFACE.
- (30) BASED ON EMCS VENDOR'S COST ESTIMATE USING ECCO CRT D5300 (\$1500) WITH INTERFACE (\$500).
- (31) BASED ON INTERDATA'S FUZ 1100 CRT DISPLAY TERMINAL (\$1500) WITH CABLE (\$60) AND ONE FOURTH OF A CONTROLLER (\$375).
- (32) BASED ON INTELLIGENT SYSTEMS CORP'S ISC 800IG COLOR CRT TERMINAL (\$1950) AND USING ONE HALF OF A MODCOMP ACI (4811) (\$840) WITH CABLE (\$60).
- (33) BASED ON INTELLIGENT SYSTEMS CORP'S ISC 800IG COLOR CRT TERMINAL (\$1950) AND HP COMMUNICATION CARD (\$575) AND CABLE (\$60).
- (34) BASED ON EMCS VENDOR'S ESTIMATE. NOTE: SOME OF THE COST FOR SPECIAL CHARACTERS IS INCLUDED IN THE PRICE.
- (35) BASED ON INTELLIGENT SYSTEMS CORP'S ISC 800IG COLOR CRT TERMINAL (\$1950) AND USING ONE HALF OF A MODCOMP ACI (4811) WITH CABLE (\$60).

- (36) BASED ON INTELLIGENT SYSTEMS CORP'S ISC 800IG COLOR CRT TERMINAL (\$1950) AND ONE FOURTH OF A INTERDATA COMMUNICATION CONTROLLER (\$350) AND CABLE (\$60).
- (37) BASED ON INTELLIGENT SYSTEMS CORP'S ISC 800IG COLOR CRT TERMINAL (\$1950) AND DIGITAL'S DL-11 TERMINAL INTERFACE (\$770) WITH CABLE (\$60).
- (38) BASED ON EMCS VENDOR'S ESTIMATE.
- (39) PAPER TAPE READER ONLY, COST BASED ON MODCOMP MODEL 4513 (\$1800), CONTROLLER MODEL 3751 (\$850) AND ONE FOURTH PERIPHERAL INTERFACE MODEL 4903 (\$500) AND A CABLE.
- (40) BASED ON THE INTERDATA PAPER TAPE PUNCH/READER WITH CONTROL BOARD.
- (41) BASED ON THE INTERDATA 9 CHANNEL, 800 BPI, 45 IPS UNIT WITH CONTROLLER.
- (42) CCU PRICE QUOTED BY EMCS VENDOR HAS DISK SYSTEM INCLUDED AS A PACKAGE ALONE WITH 192KB CORE MEMORY AND I/O DRIVERS NECESSARY TO SUPPORT THE PERIPHERALS.
- (43) EMCS VENDOR'S PRICE ESTIMATE FOR CCU PACKAGE IN FOOTNOTE 49 INCLUDED A DUAL DISK DRIVE WITH CONTROLLER. THE PRICE QUOTED HERE IS THE MARGINAL COST FOR AN ADDITIONAL DRIVE ADDED TO THE CONTROLLER. IF AN ADDITIONAL CONTROLLER (RL-11) IS USED, THE COST IS \$1,150 FOR AN EXTRA CONTROLLER.
- (44) EMCS VENDOR'S QUOTED PRICE FOR A 30 CPS PRINTER WITH KEYBOARD.
- (45) EMCS VENDOR'S QUOTED PRICE FOR COLOR CRT TERMINAL WITH 30 GRAPHICS CHARACTERS. NOTE: THIS PRICE INCLUDES SPECIAL GRAPHICS AS REQUIRED BY THE GUIDE SPEC., IN ADDITION TO THE COST OF THE COLOR CRT.
- (46) EMCS VENDOR'S QUOTED PRICE FOR A B&W CRT TERMINAL.
- (47) EMCS VENDOR'S QUOTED PRICE FOR PAPER TAPE READER AND PUNCH.
- (48) EMCS VENDOR'S QUOTED PRICE FOR TAPE UNIT 800 BPI, 9 TRACK 45-IPS WITH CONTROLLER.
- (49) EMCS VENDOR'S QUOTED PRICE FOR FAIL OVER CONTROL BOARD.
- (50) EMCS VENDOR'S QUOTED PRICE FOR INTERCOM; MASTER STATION IS \$2700 AND THE REMOTE STATION IS \$160 PER UNIT.
- (51) BASED ON HP PAPER TAPE READER MODEL 12925 (\$3300) AND PUNCH MODEL 12926A (\$5000) PRICE INCLUDES CABLE AND CONTROLLER.
- (52) BASED ON HP TAPE UNIT 79700 WITH ON710W 236, PRICE INCLUDES CABLE AND CONTROLLER.
- (53) BASED ON THE EMCS VENDOR'S ESTIMATE USING HP'S ASC11 CLOCK 59309A (\$1025) WITH INTERFACE CARD (\$600) CABLE INCLUDED.
- (54) BASED ON THE EMCS VENDOR'S ESTIMATE FOR HIS CHOICE OF CRT.

TABLE 2
SOFTWARE
MANUFACTURERS DATA

	A	B	C	D	E	F	G	VALUE USED IN STUDY
1. SYSTEM SOFTWARE								
A REAL TIME OPERATING SYSTEM	(25) 300	(1) 65,000	(21) 5,000	(33)	(26) 300	(22) 1,700	(32) 300,000	
B FORTRAN		(2) 2,000				(23) 550		
		(3) 7,000						
C BASIC		(4) 2,000				(24) 450		
		(5) 7,000						
D MATHEMATICS PACKAGE								
2. COMMAND SOFTWARE		(9) 28,000	(28) 30,000					
A GRAPHICS		(7) 18,000						
B DATA BASE CONFIGURATION		(8) 4,000						
3. APPLICATION PROGRAMS			(29) 44,000					
A TIME PROGRAM FUNCTIONS								
B EXTENDED SERVICE CONTROL								
C SOFTWARE INTERLOCKING SEQUENCES								
D ELECTRICAL DEMAND LIMITING		(27) 8,000						
E DUTY CYCLE PROGRAMS		(10) 2,000						
F POWER DEMAND STATISTICS		(11) 4,000						
G ENTHALPY/PSYCHROMETIC		(12) 2,000						
H DAMPER/ENTHALPH CONTROL		(13)						
I HEATING/COOLING RESET OPTIMIZING		(14) 6,000						
J CHILLER PLANT OPTIMIZATION		(15) 4,000						
K BOILER MANAGEMENT		(16) 4,000						
L CALCULATED POINT								
M ANALOG TOTALIZATION								
N ANALOG MONITORING								
O RUN TIME TOTALIZATION		(19) 2,000						
P ENERGY TOTALIZATION		(20)						
Q OPTIMAL START		(17) 6,000						
R POWER FAIL RESTART OF MOTORS		(18) 4,000						

TABLE 2
SOFTWARE
MANUFACTURERS DATA

	A	B	C	D	E	F	G	VALUE USED IN STUDY
4. CENTRAL COMMUNICATIONS CONTROLLER SOFTWARE		(6) 15,000	(30) 7,500					
5. FIELD INTERFACE DEVICE SOFTWARE			(31) 75					

TABLE 2. FOOTNOTES
SOFTWARE

- (1) BASED ON EMCS VENDOR'S ESTIMATES FOR RSX11M OPERATION SYSTEM.
- (2) BASED ON EMCS VENDOR'S ESTIMATES FOR STANDARD FORTRAN.
- (3) BASED ON EMCS VENDOR'S ESTIMATES FOR EXTENDED FORTRAN.
- (4) BASED ON EMCS VENDOR'S ESTIMATES FOR STANDARD BASIC.
- (5) BASED ON EMCS VENDOR'S ESTIMATES FOR EXTENDED BASIC.
- (6) BASED ON EMCS VENDOR'S ESTIMATES FOR COMMUNICATION SOFTWARE.
- (7) BASED ON EMCS VENDOR'S ESTIMATES FOR GRAPHICS PACKAGE.
- (8) BASED ON EMCS VENDOR'S ESTIMATES FOR SYSTEM 200 POINTS. FOR EACH ADDITIONAL ANALOG PT ADD \$40 AND FOR EACH ADDITIONAL BINARY POINT ADD \$20.
- (9) BASED ON EMCS VENDOR'S ESTIMATES FOR SYSTEM SOFTWARE.
- (10) BASED ON EMCS VENDOR'S ESTIMATES FOR DUTY CYCLE PROGRAM.
- (11) BASED ON EMCS VENDOR'S ESTIMATES FOR POWER DEMAND STATISTIC PROGRAM.
- (12) BASED ON EMCS VENDOR'S ESTIMATES FOR ENTHALPY MGT. SYSTEM.
- (13) PRICE INCLUDED IN ENTHALPY MGT. STATION FOR FOOTNOTE 12.
- (14) BASED ON EMCS VENDOR'S ESTIMATES FOR HEATING AND COOLING RESET OPTIMIZATION PROGRAM.
- (15) BASED ON EMCS VENDOR'S ESTIMATES FOR CHILLER PLANT OPTIMIZATION PROGRAM.
- (16) BASED ON EMCS VENDOR'S ESTIMATES FOR BOILER MANAGEMENT AND OPTIMIZATION PROGRAM.
- (17) BASED ON EMCS VENDOR'S ESTIMATES FOR OPTIMAL START/STOP PROGRAM.
- (18) BASED ON EMCS VENDOR'S ESTIMATES FOR POWER FAIL RESTART OF MOTORS.
- (19) BASED ON EMCS VENDOR'S ESTIMATES FOR RUN TIME TOTALIZATION.
- (20) ENERGY TOTALIZATION INCLUDED WITH RUN TIME TOTALIZATION PROGRAM.

(21) BASED ON HEWLETT PACKAGE 92067A RTE-4 DISK BASED OPERATING SYSTEM FOR 21MX COMPUTER ON A 5MB DISK (OPTION 31). OPERATING SYSTEM SOFTWARE SUPPORT AND UPDATES ARE \$17,580/MO.

(22) BASED ON INTERDATA OPERATING SYSTEM OS-10MT2 SUPPLIED ON DISK.

(23) BASED ON INTERDATA FORTRAN IV.

(24) BASED ON INTERDATA BASIC.

(25) BASED ON MODCOMP OPERATING SYSTEM MAX3. PRICE COVERS COST OF DOCUMENTATION.

(26) BASED ON MODCOMP OPERATING SYSTEM MAX3. PRICE COVERS COST OF DOCUMENTATION.

(27) BASED ON EMCS VENDOR'S ESTIMATE FOR ELECTRICAL DEMAND LIMITING PROGRAM.

(28) BASED ON THE VENDOR'S ESTIMATE FOR THE NUMBER OF MAN MONTHS FOR EACH TASK. (SEE TABLE BELOW). IT IS ASSUMED THE COST OF THE TASK CAN BE SPREAD OVER AT LEAST 10 JOBS. THE RATE USED IN THIS CALCULATION IS AN ESTIMATED RATE OF \$3150\$/MAN MONTHS.

COMMAND SOFTWARE

GENERAL	12
COMMAND LINE MEMORIC INTERPRETER	12
DEFINITION PROCESS	12
REPORT GENERATOR	4
INDEX	18
GRAPHICS SOFTWARE	24
CONTROL SEQUENCE SOFTWARE	6
ALARMS	12
PERIPHERAL DEVICE SHARING	2
OPERATOR'S CONTROL SOFTWARE	0
PREDICTOR/CORRECTOR PROGRAM	3
SYSTEM ACCESS CONTROL	2
FID SOFTWARE EDITING	<u>12</u>
TOTAL TIME FOR DEVELOPING	95 MAN MONTHS
COMMAND SOFTWARE	

(29) BASED ON THE VENDOR'S ESTIMATE FOR THE NUMBERS OF MAN MONTHS FOR EACH TASK. (SEE TABLE BELOW). IT IS ASSUMED THE COST OF THE TASK CAN BE SPREAD OVER AT LEAST 10 JOBS. MUCH OF THE COMMAND SOFTWARE HAS EXISTED IN MODIFIED FORM FOR SOME TIME, AND HAS BEEN USED ON PREVIOUS JOBS BEFORE THE GUIDE SPEC REQUIREMENTS. THE RATE USED FOR THIS CALCULATION IS \$3150/MAN MO. IT SHOULD BE NOTED THAT ANY NEW PROGRAM REQUIREMENT NOT LISTED IN THE GUIDE SPEC COULD GREATLY AFFECT THE SOFTWARE COST.

APPLICATIONS PROGRAMS

GENERAL	8
TIME PROGRAM FUNCTIONS	4
EXTENDED SERVICE CONTROL	6
SOFTWARE INTERLOCKING SEQUENCES	12
ELECTRICAL DEMAND LIMITING	10
DUTY CYCLE PROGRAM (DCP)	2
POWER DEMAND STATISTICS	4
ENTHALPY/PYCHROMETRIC PROGRAM	4
DAMPER/ENTHALPY CONTROL PROGRAM	8
HEATING/COOLING RESET OPTIMIZING	24
PROGRAM (H/C ROP)	8
CHILLER PLANT OPTIMIZATION	2
BOILER MANAGEMENT	1
CALCULATED POINT	24
ANALOG TOTALIZATION	2
ANALOG MONITORING	6
RUN TIME TOTALIZATION	10
ENERGY TOTALIZATION	6
OPTIMAL START	6
POWER FAIL RESTART OF MOTORS	6
TOTAL TIME FOR DEVELOPING	101
APPLICATION PROGRAM	MAN MONTHS

(30) BASED ON VENDOR'S ESTIMATE OF 24 MAN MONTHS ASSUMING A \$3150/MAN MONTH RATE AND THE COST SPREAD OVER 10 SYSTEMS.

(31) BASED ON VENDOR'S ESTIMATE OF 12 MAN MONTHS NECESSARY TO MODIFY THE PROGRAMS THAT COME WITH THE FID'S, AND ASSUMING A PROGRAMING RATE OF 3150/MAN MONTH, WITH THE COST AMORTIZED OVER 500 FID'S.

(32) VENDOR'S ESTIMATE ON TOTAL SOFTWARE COST.

(33) THE STANDARD SOFTWARE COMES WITH THE SYSTEM AT NO ADDITIONAL SOFTWARE COST.

TABLE 3
COMMUNICATION
MANUFACTURER'S DATA

	A	B	C	D	E	F	G	VALUE USED IN STUDY
1. COMMUNICATION CABLE								
A OUTSIDE ON EXISTING POLES			(1) 985 \$/1000 FT.					(2) 673 \$/1000 FT.
B INSIDE								
C BURIED			(7) 3,140 \$/1000 FT.					
D CABLE COST			(10) 275 \$/1000 FT.					
2. COAX (4)								
A OUTSIDE ON EXISTING POLES				(11) 1.50 TO 2\$/FT.				
B INSIDE (5)								
C DIRECT BURIAL OF COAX				(6) 3\$/FT.				
D CABLE COST				(3) 250 \$/1000 FT.				
3. FIBER OPTICS (8)								
4. RADIO								
5. POWER LINE MODEM		(9) 910						

TABLE 3 FOOTNOTES
COMMUNICATION
MANUFACTURER'S DATA

- (1) COST BASED ON INFORMATION SUPPLIED BY EMCS VENDOR TO RUN 1,000 FT. OF EXISTING POLES WITH FIGURE EIGHT CABLE WITHOUT ANY OBSTACLE. THREE MEN CAN PUT UP 1,000 FT OF CABLE IN ONE DAY WITH A BUCKET TRUCK USING FIGURE EIGHT CABLE.

3 MAN DAYS @ \$15/MAN HR.	3MD :: 8 MHR/MD :: \$15/MHR	=	\$360.
CABLE COST \$275/1,000 FT.		=	275.
MOUNTING HARDWARE \$20/MOUNT POINT	\$20/MP :: 10MP/100A	=	200.
BUCKET TRUCK \$150/DAY			150.
TOTAL \$985/1,000 FT.			\$985.

IF A POLE IS REQUIRED IT TAKES ABOUT A DAY TO PUT UP A POLE WITH A THREE MAN TEAM AND A AUGER TRUCK.

ONE AUGER TRUCK WITH DRIVER \$250/DAY
2 MEN AT \$16/MAN HR
POLE \$75.
COST FOR ONE POLE

2MD :: 8 MHR/MD :: \$16/MHR = \$250.
75.
\$581.

- (2) BASED ON 1978 BUILDING COST FILE - SOUTHERN EDITION FOR 5 PAIRS OF CABLE. (MATERIAL COST \$429/1,000 FT; LABOR \$240/1,000 FT.)

NOTE: THAT PRICING WILL VARY WITH TIME, LOCATION, AND WITH THE EXACT NATURE OF THE JOB. CABLE RUNS IN EXISTING BUILDING WILL COST MORE THAN IN NEW BUILDING WHILE UNDER CONSTRUCTION. OUR EXPERIENCE HAS SHOWN THIS COST TO BE ABOUT 50% MORE IN EXISTING BUILDINGS THAN IN NEW CONSTRUCTION.

- (3) INFORMATION SUPPLIED BY EMCS VENDOR FOR 1/2" SOLID SHIELD COAX.

- (4) LONG COAX CABLE RUNS MAY REQUIRE REPEATERS (LINE AMPS) EVERY 1/2 MILE, COST \$300 PER LINE AMP.

- (5) NOTE: THE COST TO RUN COAX CABLE INSIDE A BUILDING IS COMPARABLE TO THE COST OF RUNNING INSIDE SIGNAL WIRE ONCE YOU ADJUST FOR THE DIFFERENCE IN CABLE COST.

- (6) ESTIMATE SUPPLIED BY EMCS VENDOR FOR RUNNING COAX IN EXISTING BANKS.

- (7) BASED ON ESTIMATES SUPPLIED BY EMCS VENDOR FOR CABLE BURIED IN EXISTING BANKS. THE COST TO BURY CABLE IN EXISTING BANK RUNS ABOUT 400% THAT OF AERIAL CABLE.

- (8) NONE OF THE VENDOR'S CONTACTED EXPRESSED INTEREST IN USING FIBER OPTICS AT THIS TIME.

(9) BASED ON INFORMATION SUPPLIED BY EMCS VENDOR. NOTE: REPEATERS MAY BE NEEDED IF SIGNAL MUST BE TAKEN MORE THAN TWO MILES. COST OF REPEATERS IS ABOUT \$2,000. NOTE ALSO A POWER TRANSFORMER IN SIGNAL PATH MUST BE BYPASSED WITH A HIGH FREQUENCY COUPLING DEVICE.

(10) COST DATE SUPPLIED FROM EMCS VENDOR BASED ON FIGURE EIGHT CABLE FOR USE OUTDOORS ON POLES.

(11) COST ESTIMATE SUPPLIED BY EMCS VENDOR BASED ON HIS PAST EXPERIENCE USING COAX THAT WAS HUNG ON EXISTING POLES.

TABLE 4
FID'S
MANUFACTURER'S DATA

	A	B	C	D	E	F	G	VALUE USED IN STUDY
A FIELD INTERFACE (1) DEVICE (FID)	(2) \$3,000/ 22 SLOTS	(3) \$2,510/ 12 SLOT \$2,270/ 8 SLOT	(4)	(5) \$5,000 INCLUDES MODEM/ 28 SLOT	(6) \$4,284/ 5 SLOTS \$6,540/ 13 SLOTS \$8,290/ 21 SLOT	(7) LARGE \$2,500 SMALL \$1,200	(8) \$1,200/ 14 SLOTS	\$2,400
B FID SUPPORT EQUIPMENT (A) PROM PROGRAMMER (B) TEST SET (C) DIGITAL MULTI-METER (D) TESTER & ANALYZER		\$1,150 (B),(C),(D) PACKAGE \$9,300		(11) \$2,000	(15)			
C MULTIPLEXER PANELS (12) \$500 (MUX) (9)		(10) \$920/ 3 CARDS OR \$720/1 CARD						
D MODEM		(13) \$425					(14) \$350	
E FUNCTION CARDS FOR FID OR MUX (A) ANALOG OUTPUT (B) ANALOG INPUT (C) BINARY INPUT (D) BINARY OUTPUT		\$70/4 PTS \$970/16 PTS SEE COMBO BELOW SEE COMBO BELOW		\$375/4 PT \$100/8 PTS \$150/8 PTS	\$610/4 PTS (16)\$260/4 PTS \$325/8 PTS (17)\$290/4 PTS w/ STATUS FEED- BACK		\$625/4 PTS \$600/8 PTS \$260/12 PTS \$300/8 PTS	(19) \$368/PT (19) \$110/PT (19) \$ 33/PT (19) \$ 43/PT (19) \$ 61/PT
(E) COMBO OF A, B, C, D		(18) \$1,040						

TABLE 4 FOOTNOTES
FID'S

- (1) FID'S - PRICES REFLECT "EMPTY" FID'S, I.E. NO FUNCTION CARDS BUT WITH POWER SUPPLY, CPU CARD, MEMORY AND OTHER SUPPORTING ELECTRONICS. AN EXCEPTION IS MANUFACTURER F. SEE NOTE (7) BELOW.
- (2) FID HAS A "COMMON CAGE" WITH SIX SLOTS REMAINING AFTER SUPPORTING ELECTRONICS HAVE BEEN INSTALLED. THEN, ADDITIONAL CAGES ARE ADDED AS NEEDED WITH EACH CAGE CONTAINING 16 CARD SLOTS.
- (3) THE 12 CARD SLOT FID CAN BE EXPANDED (DOUBLE IN CAPACITY) BY ADDING A REMOTE CHASSIS UP TO ABOUT 1000 FEET FROM THE MAIN FID. THE CHASSIS COMMUNICATES WITH THE FID VIA A RS422 PATCH, CONTAINS 12 SLOTS AND COST \$1,470.
- (4) USE FID'S MANUFACTURED BY ANOTHER EMCS OEM.
- (5) EMCS VENDOR'S ESTIMATE FOR A BARE FID.
- (6) ONE FID CARD SLOT IS UTILIZED BY AN A/D CONVERTER CARD IF THE FID HAS AT LEAST 1 ANALOG POINT. (PRACTICALLY ALL EMCS FID'S HAVE ANALOG POINTS).
- (7) PRICE BASED ON A FULL FID CAPABLE OF HANDLING ABOUT: 48 DIGITAL OUT, 32 DIGITAL IN, 32 ANALOG IN. ANALOG OUT POINTS CAN BE DONE USING ONE DIGITAL OUT AND ONE DIGITAL IN POINT. THE SMALL FID COMES PREPACKAGED WITH A SINGLE, COMBINATION FUNCTION CARD WHICH CAN HANDLE: 16 DIGITAL IN, 16 DIGITAL OUT, 8 (SOON TO BE 16) ANALOG IN. ANALOG OUT POINTS FORMED AS DESCRIBED ABOVE.
- (8) DOES NOT NEED MODEM UNLESS TRANSMITTING FURTHER THAN ABOUT 2000 FEET.
- (9) MUX'S - MOST MANUFACTURERS DO NOT HAVE A SMALL, INEXPENSIVE MUX FOR LOW POINT DENSITY BUILDINGS. THEY WOULD HAVE TO BID BASED ON A FID IN EACH BUILDING.
- (10) EMCS VENDOR OFFERS MUX'S USING FUNCTION CARDS WHICH ARE THEMSELVES MICROPROCESSOR-BASED. THEY CAN PERFORM CERTAIN STAND ALONE FUNCTIONS, SUCH AS TIME OF DAY START/STOP AND DUTY CYCLING, WHICH ARE NORMALLY THOUGHT OF AS FID CAPABILITIES. THIS TENDS TO EXTEND THE CONCEPT OF DISTRIBUTED PROCESSING EVEN TO MUX-CONTROLLED BUILDINGS.
- (11) EMCS VENDOR'S TEST BOX FOR A FID THAT CAN SIMULATE THE COMPUTER INTERFACE.
- (12) BASED ON EMCS VENDOR'S ESTIMATE FOR A LOW POINT DENSITY MULTIPLEXER.
- (13) BASED ON EMCS VENDOR'S ESTIMATE FOR 300 BAUD MODEM.
- (14) BASED ON EMCS VENDOR'S ESTIMATE FOR A GENERAL PURPOSE LOW SPEED MODEM.
- (15) UNDER DEVELOPMENT AT THIS TIME. NO PRICE AVAILABLE.
- (16) ANALOG INPUT CARD REQUIRES ONE SNAP-ON ANALOG TRANSMITTER (AT) PER POINT AT ABOUT \$45 PER AT.

(17) START/STOP CARD HAS STATUS FEEDBACK POINTS INCORPORATED ON SAME CARD.

(18) THIS COMBINATION CARD HAS THE FOLLOWING POINT CAPACITIES: 16 BINARY IN, 4 BINARY OUT, 4 ANALOG OUT. THE 16 BINARY IN CAN BE CONFIGURED AS 16 ANALOG IN.

(19) POINT PRICES ARE ADJUSTED UPWARD SOMEWHAT TO ACCOUNT FOR THE FACT THAT OFTEN THE MAXIMUM POINT CAPACITY OF A FID FUNCTION CARD IS NOT USED. FOR EXAMPLE, IF A FID HAS ONLY TWO BINARY INPUT POINTS, A "WHOLE" CARD OF 4, 8, OR 12 POINTS, ETC., WOULD BE USED. ALTHOUGH THIS IS FINE FOR FUTURE EXPANSION, IT MEANS INITIALLY, THE PER POINT PRICE ESTIMATE OF FUNCTION CARDS SHOULD BE HIGHER THAN THE FIGURE ARRIVED AT BY DIVIDING THE CARD COST BY THE MAXIMUM POINTS THAT CARD WILL HANDLE. THE PRICES SHOWN ASSUMED THE FOLLOWING AVERAGE USAGE:

	MAX. CARD POINT CAPACITY	POINTS ACTUALLY USED
ANALOG OUT BINARY OUT	4	2
	4	2
	8	4
BINARY IN OR, ANALOG IN	4	3
	8	6
	12	9
	16	12

IT SHOULD BE NOTED THAT THESE PER POINT PRICES ARE ESTIMATES. ACTUAL COST IN A PARTICULAR FID IS GREATLY INFLUENCED BY SEVERAL FACTORS INCLUDING:

- FID POINT TOTAL - LARGE POINT TOTALS MEAN THAT SEVERAL "WHOLE" CARDS COULD BE USED WITH ONLY THE LAST ONE LIKELY TO BE PARTIALLY USED.
- MANUFACTURER - TOTAL POINTS HANDLED ON AN INDIVIDUAL CARD VARIES FROM ONE MANUFACTURER TO THE NEXT. ALSO, SOME MANUFACTURERS HAVE DEVELOPED COMBINATION CARDS WHICH MIGHT FIT A PARTICULAR CONFIGURATION WELL ENOUGH TO AVOID THE USE OF ONE OR MORE TYPE OF SINGLE FUNCTION CARDS ALTOGETHER.

TABLE 5
SENSORS AND CONTROLS

THESE POINT COSTS DO NOT INCLUDE THE COST OF A SHARE OF AN FID FUNCTION CARD (SEE TABLE 4, ITEM 3, ABOVE).

		MATERIAL	*LABOR
A. START/STOP, OPEN/CLOSE, ON/OFF			
1. MOTOR STARTER, SINGLE SPEED			
(A) RELAY INTERFACE TO MOTOR STARTER		\$ 36	\$ 16
(B) 50 FT. OF WIRING AND CONDUIT		12	54
	TOTAL A.1	\$ 48	\$ 70
2. MOTOR CONTROL, TWO SPEED			
(A) RELAY INTERFACE (2) TO MOTOR		\$ 72	\$ 32
(B) 50 FT. OF WIRING AND CONDUIT		12	54
	TOTAL A.2	\$ 84	\$ 86
3. VALVE OPEN/CLOSE			
(A) RELAY INTERFACE TO VALVE		\$ 36	\$ 14
(B) 50 FT. OF WIRING AND CONDUIT, OR PNEUMATIC TUBING		12	54
(C) ELECTRIC-TO-PNEUMATIC SWITCH		24	10
	TOTAL A.3	\$ 72	\$ 78
B. TEMPERATURE MEASUREMENT POINTS			
1. DUCT, AIR, AVERAGING			
(A) AVERAGING SENSOR		\$ 54	\$ 25
(B) 50 FT. OF WIRING AND CONDUIT		12	54
	TOTAL B.1	\$ 66	\$ 79
2. DUCT, AIR, BULB SENSOR			
(A) RTD		\$ 36	\$ 20
(B) 50 FT. OF WIRING AND CONDUIT		12	54
	TOTAL B.2	\$ 48	\$ 74
3. SPACE, AIR			
(A) SENSOR, W/COVER		\$ 30	\$ 30
(B) 50 FT. OF WIRING AND CONDUIT		12	54
	TOTAL B.3	\$ 42	\$ 84

4. LIQUID, SENSOR IN EXISTING WELL
 (A) RTD
 (B) 50 FT. OF WIRING AND CONDUIT
 NOTE: COST OF INSTALLING NEW WELLS VARY FROM \$100 TO OVER \$1,000 EACH DEPENDING ON HOW MANY WELLS, IF SYSTEM TO BE DRAINED, ACCESSIBILITY, ETC.
- C. PRESSURE, DIFFERENTIAL
- L. ANALOG
 (A) DP CELL W/TRANSMITTER, PLATES, FLANGES
 (B) 50 FT. OF WIRING AND CONDUIT
2. SWITCH
 (A) TRANSDUCER
 (B) 50 FT. OF WIRING AND CONDUIT
- D. CONTACT (ALARM, STATUS, ETC)
- L. 50 FT. OF WIRING AND CONDUIT
 NOTE: SHOULD ADD ABOUT \$50 LABOR IF SEVERAL SAFETY ALARMS MUST BE WIRED IN SERIES.
- E. RELATIVE HUMIDITY
1. DUCT OR SPACE
 (A) SENSOR
 (B) 50 FT. OF WIRING AND CONDUIT

\$ 30
 12
\$ 42

TOTAL B.4

\$ 10
 54
\$ 64

\$ 734
 12
\$ 744

TOTAL C.1

\$ 300
 54
\$ 354

\$ 50
 12
\$ 62

TOTAL C.2

\$ 40
 54
\$ 94

\$ 12
 12
\$ 24

TOTAL D.1

\$ 54
 54
\$ 108

\$ 150
 12
\$ 162

TOTAL E.1

\$ 20
 54
\$ 74

F. MISCELLANEOUS WIRING COST
 USING SOUTHERN EDITION OF BUILDING COST FILE FOR LABOR AND CONDUIT,
 AND MANHATTEN CABLE CO. MATERIAL PRICES FOR WIRE.

1. CONDUIT, 1 INCH, \$/FT.	\$0.370	\$1.300
2. CONDUIT, 1/2 INCH, \$/FT.	0.160	0.980
3. CABLE, 12 PAIR, \$/FT.	1.299	0.280
4. CABLE, 5 PAIR, \$/FT.	0.670	0.244
5. CABLE, 1 PAIR, \$/FT.	0.074	0.098

NOTE: COST OF CABLE FLUCTUATES CONSIDERABLY WITH CURRENT COPPER PRICES.

7.0 PRIORITIZATION ANALYSIS

On a Naval installation there are many possible uses of an Energy Monitoring and Control System (EMCS). Some of those uses are worthwhile from a cost and energy savings standpoint, and some are not. Each EMCS installed using Energy Conservation Investment Program (ECIP) funds must be justified according to certain economic and energy conservation criteria. Each EMCS function to be applied to each existing energy consuming system (call this a system/function) should be analyzed to assure that that system/function meets the criteria. System/functions which are not justified should be deleted from the project.

Once system/functions are eliminated which are not justifiable, the remaining system/functions must be analyzed. In general, no EMCS project includes enough funds to perform all justifiable uses of an EMCS on a particular base. An analysis must be performed which determines which of the many alternatives should be performed with the funds available. Such an analysis is called a "prioritization analysis". The prioritization analysis determines which of a set of alternatives should be included in the project to provide the most savings for the least investment.

The basic steps in performing a prioritization analysis for an EMCS (or any other project involving a large number of alternatives and a limited budget) are:

1. Determine alternatives to be considered.
2. Calculate savings for each alternative (Note that savings may be in dollars or energy units, depending on the criteria.)
3. Calculate investment for each alternative
4. Calculate the savings/investment ratio for each alternative
5. Prepare a list of alternatives ranked based on savings/investment ratio (best alternative at top of list, worst at bottom)
6. Cumulate the investment costs for the alternatives until the total reaches the budget amount. This establishes the cutoff line.
7. All alternatives above the cutoff line on the list should form the basic project. Alternatives listed below the cutoff line should be deleted from the project (or be included as additive bid items).

The prioritization process described above is applicable to EMCS projects. The first step is to determine the alternatives to be considered. There are two approaches to this. One is to consider each individual system/function as an alternative. This results in anywhere from 600 to 5,000 individual alternatives. Such an approach is very difficult to perform using manual calculation techniques. Computer programs have been written which can accomplish this type of analysis, however, those programs are highly specialized, expensive to run, and require intimate familiarity on the part of the user to be used effectively. A second approach is to consider all work within each building as an alternative. This is a more

practical method, and is more consistant with the general level of accuracy of the analysis.

Once the alternatives are determined, savings (in energy BTU's and dollars) and investment may be estimated as discussed in Section 5 and 6 of this report. Tabulation, ranking, and cutoff of the alternatives is illustrated in the example problem, Section 9.0 of this report.

It is very important to note that current ECIP projects are funded based on their E/C (energy saved (in million BTU) divided by thousand dollars invested) ratio as long as the project has an S/I (life cycle dollar savings divided by dollars invested) ratio greater than one. All projects which have an S/I ratio greater than one are prioritized for funding strictly on their E/C ratios. Projects which have higher E/C ratios will be funded prior to projects with lower E/C ratios, regardless of what the S/I ratios actually are for those projects (as long as the S/I ratio is greater than one).

8.0 OVERALL ECONOMIC ANALYSIS

An overall economic analysis must be performed for each Energy Monitoring and Control System funded under the Energy Conservation Investment Program (ECIP). Criteria for the required analysis is as follows (according to instructions issued from the Office of the Chief of Naval Operations dated 27 July 1978):

1. EMCS ECIP projects must be cost-effective based on a savings-to-investment (S/I) ratio greater than one utilizing a life cycle cost analysis.
2. Each project must have an energy savings-to-investment ratio of at least the following values for annual million BTU's (MBTU's) saved per \$1000 of total investment (E/C ratio): FY-80, 22; FY-81, 20; FY-82, 19; FY-83, 18; and FY-84, 17.
3. Projects shall be supported with engineering calculations in sufficient detail to allow validation of energy savings.
4. Actual fuel heating value rates should be used when known. If not known, the following conversion factors will be used to permit standardized project evaluation comparisons:

Distillate Fuel Oil.	138,700 BTU/gal
Residual Fuel Oil.	150,000 BTU/gal
Natural Gas.	1,031,000 BTU/1000 cu.ft.
LPG, Propane, Butane	95,500 BTU/gal
Bituminous Coal.	24,580,000 BTU/Short Ton
Purchased Steam.	1,390 BTU/lb
Electrical Source Fuel	11,600 BTU/KWH

5. Boiler efficiencies should be included in the calculation of savings from reduced steam consumption. The resulting reduction in fuel input and boiler feedwater represent a real cost avoidance when steam consumption is reduced. The "as-consumed" cost of fuel and electricity shall be used in determining energy dollar savings. The energy costs, as reported by each activity in the monthly Defense Energy Information System (DEIS-II) report, are "as-consumed" costs. An "Activity Rate or Host Rate", which includes overhead and maintenance costs, should not be used for calculating savings. Such costs do not normally change with small percentage reductions in overall steam consumption.

6. Energy, material, and labor prices should be escalated from current rates to those projected for 30 September of the fiscal year for which the project is submitted for funding. Unless more definitive future prices can be determined or predicted for an individual activity, the following rates are to be used for escalation:

	<u>FY-79</u>	<u>FY-80</u>	<u>FY-81</u>	<u>FY-82</u>	<u>FY-83</u>
Design & Construction	7.0%	6.5%	6.0%	6.0%	6.0%
Operations & Maintenance	6.4%	6.2%	5.6%	5.6%	5.6%
Coal	10.0%	10.0%	10.0%	10.0%	10.0%
Fuel Oil	16.0%	16.0%	14.0%	14.0%	14.0%
Natural Gas & LPG	15.0%	15.0%	14.0%	14.0%	14.0%
Electricity (KWH & KW)	16.0%	16.0%	13.0%	13.0%	13.0%

7. The life cycle cost analysis used to determine the project's savings-to-investment ratio shall utilize a base fiscal year commencing on 1 October following the project's programmed year. The long-term differential escalation rates below are to be used for computing the present worth of recurring annual costs and benefits if more definitive data is not available at individual activities.

Operations & Maintenance	0%	Natural Gas & LPG	8%
Coal	5%	Electricity (KWH & KW).	7%
Fuel Oil	8%		

8. The present worth factors for multiplication of recurring annual savings can be selected from the appropriate differential escalation rate column in the DISCOUNT FACTORS table below.

ECIP DIFFERENTIAL ESCALATION RATES

<u>ECONOMIC LIFE IN YEARS</u>	<u>O&M COSTS 0%</u>	<u>COAL 5%</u>	<u>ELECTRICITY 7%</u>	<u>OIL & GAS 8%</u>
15	7.980	10.798	12.278	13.112

9. Economic life is the period of time over which the life cycle benefits to be gained from a project may reasonably be expected to accrue. As

such, the economic life may differ from its physical and technological life. The economic lives below may be used as guides, and ordinarily will not be exceeded.

<u>CATEGORY</u>	<u>ECONOMIC LIFE</u>
ENERGY MONITORING AND CONTROL SYSTEMS	15 years

An ECIP economic analysis summary format is included on Figure No. 6 to illustrate the minimum life cycle costing analysis necessary to determine a savings-to-investment ratio.

The project cost for line 1a of the economic analysis format is the cost of construction plus the cost of supervision, inspection and overhead. The project cost should include contingencies. The design costs in line 1b are not to include any design or survey costs which have already been obligated.

ECIP ECONOMIC ANALYSIS SUMMARY

ACTIVITY & LOCATION _____ P- _____

TITLE OF PROJECT _____ FY- _____

INVESTMENT

1. PROJECT COSTS (Economic life of _____ years)
 - a. Project cost escalated to end of program year.... \$ _____
 - b. Design costs not yet obligated \$ _____
 - c. Total Project Cost (a + b) \$ _____

SAVINGS

2. ANNUAL ELECTRICITY SAVINGS: KWH: _____
 - a. Equivalent energy: KWH x 0.0116 (MBTU's: \$ _____)
 - b. Cost per KWH at end of program year \$ _____
 - c. First year annual dollar savings (KWH x b) \$ _____
 - d. Differential escalation present worth factor
 - e. Discounted savings (c x d) \$ _____
3. ANNUAL ENERGY SAVINGS (TYPE: _____ MBTU's: _____)
 - a. Cost per MBTU at end of program year \$ _____
 - b. First year annual dollar savings \$ _____
 - c. Differential escalation present worth factor
 - d. Discounted savings (b x c) \$ _____
4. ANNUAL ENERGY SAVINGS (TYPE: _____ MBTU's: _____)
 - a. Cost per MBTU at end of program year \$ _____
 - b. First year annual dollar savings \$ _____
 - c. Differential escalation present worth factor
 - d. Discounted savings (b x c) \$ _____
5. ANNUAL OTHER-THAN-ENERGY SAVINGS (OR COSTS)
 - a. Labor \$ _____
 - b. Material & Other \$ _____
 - c. Total (a + b) \$ _____
 - d. 10% Discount Factor \$ _____
 - e. Discounted Other-than-energy savings (or costs) . \$ _____
6. TOTAL FIRST YEAR ANNUAL SAVINGS (2c + 3b + 4b + 5c) .. \$ _____
7. TOTAL DISCOUNTED SAVINGS (2e + 3d + 4d + 5e) \$ _____

COST ESCALATION

Current	Elec	\$	x	x	x	x	=	\$
rates	Oil	\$	x	x	x	x	=	\$
as of	Gas	\$	x	x	x	x	=	\$
		\$	x	x	x	x	=	\$

RATIOS

8. DISCOUNTED SAVINGS/INVESTMENT RATIO (Line 7 ÷ 1c)
9. TOTAL MBTU SAVINGS _____ ÷ (Line 1a ÷ 1000) YRS
10. SIMPLE PAYBACK PERIOD (1a ÷ Line 6) YRS

NOTE: For ETAP projects use line 1c in lines 9 and 10 in lieu of 1a.

9.0 SAMPLE NAVAL BASE

In order to demonstrate the analysis discussed in this report, a hypothetical Naval Base has been created on which the analysis has been performed. This procedure has been prepared for use by professional engineering personnel. It is not possible to describe completely all activities involved in an engineering design process. For this reason, this section is meant only to be used as a framework for EMCS analysis. Every military base is different, and parts of the process described herein must be adapted, added to, or ignored as the situation requires. The judgement required to make these decisions requires a mechanical and electrical engineering design team fully familiar with the mechanical and electrical systems an EMCS is to control and how that control is to be accomplished.

9.1 EXAMPLE PROBLEM DESCRIPTION

The example problem chosen is a hypothetical five building Naval Base. The five buildings and the systems serving those buildings have been chosen as typical of the type found on many Naval Bases. This approach for a step by step explanation was chosen so that the principles of each step can be clearly explained and illustrated without being confused by the complexity and sheer volume of an analysis of an actual Base (from 10 to 100 times the complexity of this simple five building example).

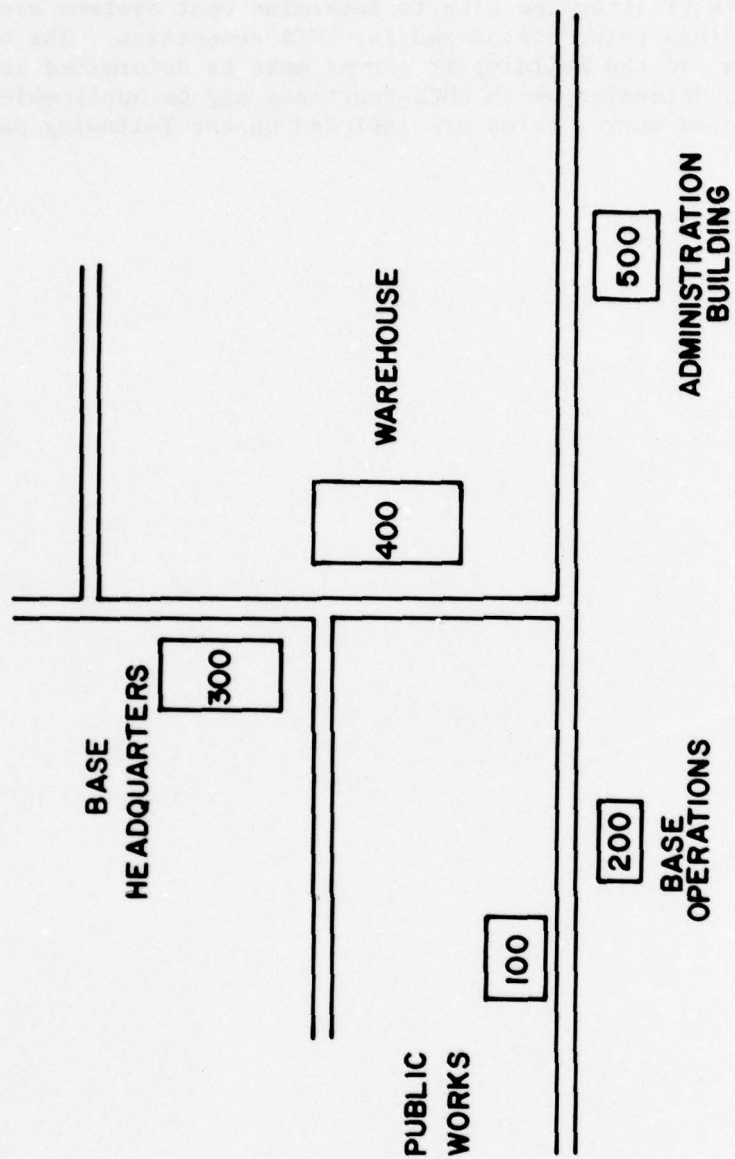
The buildings which comprise the hypothetical Naval Base and the systems within each building are listed below:

BUILDING NUMBER:	100
USAGE:	PUBLIC WORKS
SYSTEMS:	Hot Water Boiler Air Cooled Chiller Multizone Air Handler
BUILDING NUMBER:	200
USAGE:	BASE PERSONNEL
SYSTEMS:	Steam Boiler Single Zone Split System
BUILDING NUMBER:	300
USAGE:	BASE HEADQUARTERS
SYSTEMS:	2 Hot Water Boilers Air Cooled Chiller Single Zone Air Handler 2 Multizone Air Handlers
BUILDING NUMBER:	400
USAGE:	WAREHOUSE
SYSTEMS:	Steam Unit Heater System Steam Boiler
BUILDING NUMBER:	500
USAGE:	ADMINISTRATION BUILDING
SYSTEMS:	Hot Water Boiler Single Zone Split System

A map of the Sample Naval Base is included on Figure 7.

Criteria for this example analysis will be assumed to require the use of government furnished telephone lines.

Another criterion used will be the assumption that the purpose of the EMCS is to provide energy savings through control of energy consuming equipment. This is consistent with current policy. Performing the analysis to optimize monetary savings is very simple if that were given as the desired end.



SAMPLE NAVAL BASE
FIGURE 7

9.2 FIELD INVESTIGATION

Field investigation is visiting the site to determine what systems are present in the buildings being considered for EMCS connection. The operation of each system and the building it serves must be determined in sufficient detail to determine which EMCS functions may be applicable to each system. Completed survey forms are included on the following pages.

SURVEY AND BUILDING DESCRIPTION FORM

Building Number: 100 Usage: Public Works

Gross Area Sq. Ft.: 14,000 No. Floors: 1

Approx. Floor to Floor Height: 12'

Approx. Glass Dimensions: Height 4' Width 3'

Type of Glass: single glazed clear

Glass Shading: External — Internal blinds

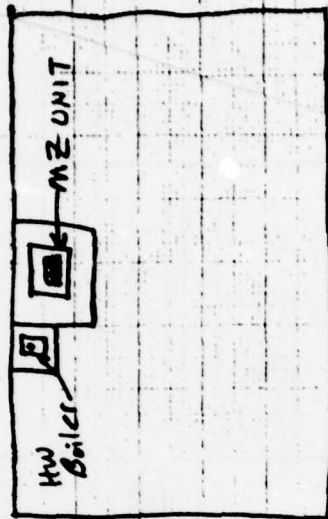
"U" Factor: Roof .15 Wall .2 Glass 1.0

Glass SC: .56

Critical Areas: NONE

Notes: occupied 730-1630 M-F

A/C CHILLER



~20% Glass
Block const

Sys #	Type:	(SZ)	(TR)	(TS)	(TR)
1	Boiler				
	Chiller				
	Dx Unit				
	Central				
	Other:				
	Capacity:				
	Pump HP:				
	Fan HP:				
	Comp HP:				
	Other HP:				
	Operation (Annual)				
	Year Round				
	Summer Only				
	Winter Only				
	Other:				
	Operation (Daily)				
	1 Shift				
	2 Shift				
	3 Shift				
	Other:				
	Existing Controls:				
	Time Clock				
	O.A. Reset				
	Other:				
	Notes:				
2	Boiler				
	Chiller				
	Dx Unit				
	Central				
	Other:				
	Capacity:				
	Pump HP:				
	Fan HP:				
	Comp HP:				
	Other HP:				
	Operation (Annual)				
	Year Round				
	Summer Only				
	Winter Only				
	Other:				
	Operation (Daily)				
	1 Shift				
	2 Shift				
	3 Shift				
	Other:				
	Existing Controls:				
	Time Clock				
	O.A. Reset				
	Other:				
	Notes:				
3	Boiler				
	Chiller				
	Dx Unit				
	Central				
	Other:				
	Capacity:				
	Pump HP:				
	Fan HP:				
	Comp HP:				
	Other HP:				
	Operation (Annual)				
	Year Round				
	Summer Only				
	Winter Only				
	Other:				
	Operation (Daily)				
	1 Shift				
	2 Shift				
	3 Shift				
	Other:				
	Existing Controls:				
	Time Clock				
	Economizer				
	Deck Reset				
	Other:				
	Notes:				
4	Boiler				
	Chiller				
	Dx Unit				
	Central				
	Other:				
	Capacity:				
	Pump HP:				
	Fan HP:				
	Comp HP:				
	Other HP:				
	Operation (Annual)				
	Year Round				
	Summer Only				
	Winter Only				
	Other:				
	Operation (Daily)				
	1 Shift				
	2 Shift				
	3 Shift				
	Other:				
	Existing Controls:				
	Time Clock				
	Economizer				
	Deck Reset				
	Other:				

SURVEY AND BUILDING DESCRIPTION FORM

Building Number: 200 Usage: Base Personnel

Gross Area Sq. Ft.: 7000 No. Floors: 1

Approx. Floor to Floor Height: 11'

Approx. Glass Dimensions: Height Width

Type of Glass: single, clear

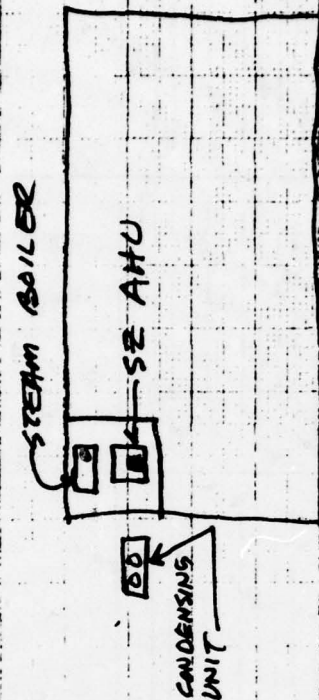
Glass Shading: External — Internal drapes

"U" Factor: Roof .20 Wall .25 Glass 1.0

Glass SC: .56

Critical Areas:

Notes: occupied 730-1630 M-F



*~ 10% glass
wood frame const.*

[illegible]

SURVEY AND BUILDING DESCRIPTION FORM

Building Number: 300 Usage: Base Headquarters

Gross Area Sq. Ft.: 51,000 No. Floors: 2

Approx. Floor to Floor Height: 12'

Approx. Glass Dimensions: Height 4' Width 3'

Type of Glass: single, gray tint

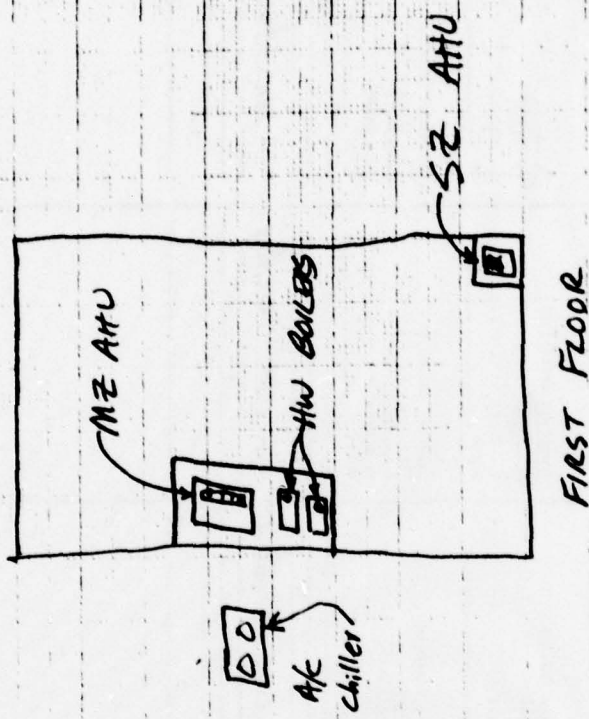
Glass Shading: External - Internal -

"U" Factor: Roof .10 Wall .12 Glass 1.0

Glass SC: .45

Critical Areas: _____

Notes: _____



Sys 1 142

Type: (TR) (HV) (SP) (FU) (STM)
 APU
 Unit Htr. (HV) (SP) (FU) (STM)
 Fan Coil (2) (4) pipe
 Convactor (HV) (STM)
 Other

Capacity: 1,500,000 and BTU/hr.
 5 each

Pump HP: 200
 Comp HP: 10
 Fan HP: 10
 Other HP:

Operation (Annual)

Year Round
 Summer Only
 Winter Only
 Other

Operation (Daily)

1 Shift
 2 Shift
 3 Shift
 Other

Existing Controls:

Time Clock
 Economizer
 Deck Reset
 Other:

Notes:

Sys 1 3

Type: (TR) (HV) (SP) (FU) (STM)
 APU
 Unit Htr. (HV) (SP) (FU) (STM)
 Fan Coil (2) (4) pipe
 Convactor (HV) (STM)
 Other

Capacity: 160 tons BTU/hr.
 18

Pump HP: 200
 Comp HP: 10
 Fan HP: 10
 Other HP:

Operation (Annual)

Year Round
 Summer Only
 Winter Only
 Other

Operation (Daily)

1 Shift
 2 Shift
 3 Shift
 Other

Existing Controls:

Time Clock
 Economizer
 Deck Reset
 Other:

Notes:

runs 24 hrs/day

Sys 1 4

Type: (TR) (HV) (SP) (FU) (STM)
 APU
 Unit Htr. (HV) (SP) (FU) (STM)
 Fan Coil (2) (4) pipe
 Convactor (HV) (STM)
 Other

Capacity: 30,000
 30

Pump HP: 30
 Comp HP: 10
 Fan HP: 10
 Other HP:

Operation (Annual)

Year Round
 Summer Only
 Winter Only
 Other

Operation (Daily)

1 Shift
 2 Shift
 3 Shift
 Other

Existing Controls:

Time Clock
 Economizer
 Deck Reset
 Other:

Notes:

runs 24 hrs/day

Sys 1 5

Type: (TR) (HV) (SP) (FU) (STM)
 APU
 Unit Htr. (HV) (SP) (FU) (STM)
 Fan Coil (2) (4) pipe
 Convactor (HV) (STM)
 Other

Capacity: 18,000
 18

Pump HP: 18
 Comp HP: 10
 Fan HP: 10
 Other HP:

Operation (Annual)

Year Round
 Summer Only
 Winter Only
 Other

Operation (Daily)

1 Shift
 2 Shift
 3 Shift
 Other

Existing Controls:

Time Clock
 Economizer
 Deck Reset
 Other:

Notes:

runs 24 hrs/day

Sys 1 6

Type: (TR) (HV) (SP) (FU) (STM)
 APU
 Unit Htr. (HV) (SP) (FU) (STM)
 Fan Coil (2) (4) pipe
 Convactor (HV) (STM)
 Other

Capacity: 20,000
 20

Pump HP: 20
 Comp HP: 10
 Fan HP: 10
 Other HP:

Operation (Annual)

Year Round
 Summer Only
 Winter Only
 Other

Operation (Daily)

1 Shift
 2 Shift
 3 Shift
 Other

Existing Controls:

Time Clock
 Economizer
 Deck Reset
 Other:

Notes:

runs 24 hrs/day

SURVEY AND BUILDING DESCRIPTION FORM

Building Number: 400 Usage: Warehouse

Gross Area Sq. Ft.: 70,000 No. Floors: 1

Approx. Floor to Floor Height: 18

Approx. Glass Dimensions: Height Width

Type of Glass: NONE

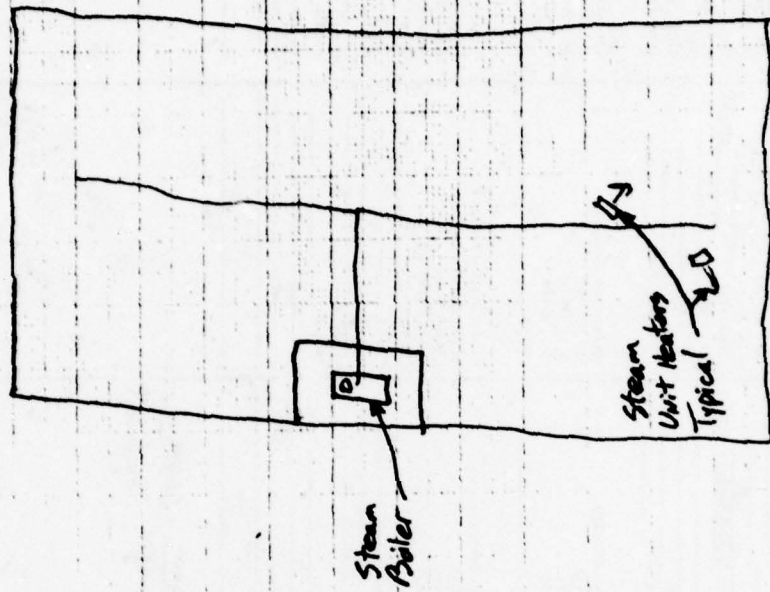
Glass Shading: External Internal

"U" Factor: Roof .20 Wall .25 Glass

Glass SC:

Critical Area:

Notes: occupied 730-1630 M-F



[illegible]

SURVEY AND BUILDING DESCRIPTION FORM

Building Number: 500 Usage: Administration Building

Gross Area Sq. Ft.: 13000 No. Floors: 1

Approx. Floor to Floor Height: 12'

Approx. Glass Dimensions: Height 5' width 2.5'

Type of Glass: single, clear

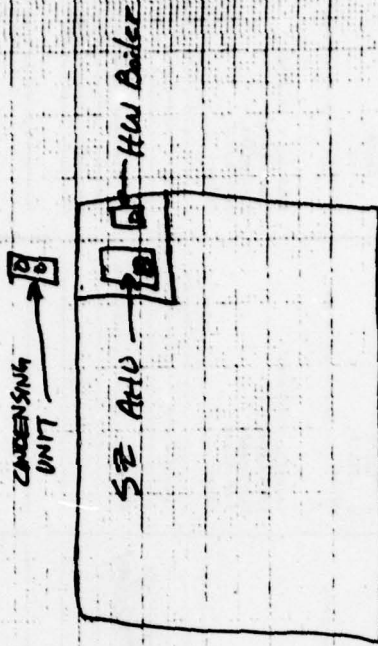
Glass Shading: External — Internal blinds

^aU Factor: Roof .15 Wall .20 Glass 1.0

Glass SC: .56

Critical Areas: —

Notes: occupied 730-1630 M-F



[illegible]

9.3 SAVINGS ANALYSIS

The savings resulting from EMCS installation on the SAMPLE NAVAL BASE are calculated in this section. A summary of the equations used in estimating the savings is included on the following pages. Following that is a summary of computerized simulation results for the analysis of functions which are not easily calculated manually. Also included are example computer program output summaries. The actual savings - cost calculation worksheets for the Sample Naval Base are included at the end of Section 9.4 Cost Analysis.

Note: Special attention should be paid to the fact that false duplication of calculated savings must be avoided. EMCS functions are interrelated and that fact must be accounted for as discussed in Section 5.0. If both time scheduled operation and duty cycling are to be performed on a system then the duty cycling savings would have to be calculated based on only the time period the system is turned on by the time scheduled operation function.

9.3.1 SAVINGS EQUATION SUMMARY

Symbols - The following symbols are used in the savings calculation equations:

C	=	control efficiency factor, use 1.0 if no time clock existing and 0.3 if time clock is existing.
D	=	fraction of an hour which system may be cycled off during critical electrical demand situations, use 15 minutes per hour.
EFLH	=	equivalent full load hours, annually. Assume 1000 EFLH for both heating and cooling.
H	=	number of hours of required operation per year
HS	=	number of hours in summer where system may be shut off because the outside temperature is below a limit.
HW	=	number of hours in winter where system may be shut off because the outside temperature is above a limit.
I	=	maximum heat transfer capacity of device in THERMS.
KW/HP	=	conversion at 0.746 KW/HP
L	=	load factor, use 0.8 to account for combination of diversity, motor efficiency, power factor, and motor oversizing
M	=	number of months during which load operates, for refrigeration equipment use 6 months/year, air handlers 12 months/year.
O	=	fraction of an hour which system may be cycled off for consumption reduction, use 10 minutes per year
OD	=	number of days of required operation per year.
PECD	=	percent energy consumption decrease, annually (expressed in decimal, i.e. 1% = .01), use 1% savings.
PEI	=	percent efficiency increase per °F increase/decrease in CHW/CDW temperature (expressed in decimal, i.e., 1% = .01), use 1.5% efficiency increase per degree F.
SKW	=	Kilowatt demand savings
SKWH	=	annual Kilowatt hour savings
STHERMS	=	annual therms heating savings

Time Scheduled Operation

- ° Cooling Savings - Simulation (do not include auxiliaries)
- ° Heating Savings - Simulation (do not include auxiliaries)
- ° Auxiliary Savings (fans, pumps, constant running apparatus) -

$$\begin{aligned} \text{SKWH} &= \text{HP} \times \text{L} \times \text{KW/HP} \times (8760 - \text{H}) \times \text{C} = \text{HP} \times .8 \times .746 \times (8760 - \text{H}) \times \text{C} \\ &= \text{HP} \times (8760 - \text{H}) \times \text{C} \times .597 \end{aligned}$$

HP = total nameplate HP of constant loads.

Duty Cycling

- ° Heating and Cooling Savings - Assume None
- ° Auxiliary Savings (fans, pumps, constant running motors) -

$$\begin{aligned} \text{SKWH} &= \text{HP} \times \text{L} \times \text{O} \times \text{H} \times \text{KW/HP} = \text{HP} \times 0.8 \times 10/60 \times \text{H} \times .746 \\ &= \text{HP} \times \text{H} \times .099 \end{aligned}$$

HP = total nameplate HP of constant loads.

Demand Limiting

- ° SKW = $\text{HP} \times \text{L} \times \text{KW/HP} \times \text{D} \times \text{M} = \text{HP} \times 0.8 \times .746 \times 15/60 \times \text{M}$
= $\text{HP} \times \text{M} \times 0.149$

HP = total electrical load of system (fans, pumps, compressors, etc.)

Start/Stop Optimization

- ° Cooling Savings - Assume None
- ° Heating Savings - Assume None
- ° Auxiliary Savings -

$$\begin{aligned} \text{SKWH} &= \text{HP} \times \text{L} \times \text{KW/HP} \times \text{T} \times \text{OD} = \text{HP} \times .8 \times .746 \times .5 \times \text{OD} \\ &= \text{HP} \times \text{OD} \times 0.298 \end{aligned}$$

Outside Air Limit Shutoff

- ° Auxiliary Savings (fans, pumps, etc.) -

$$\begin{aligned} \text{SKWH} &= \text{HP} \times \text{L} \times \text{KW/HP} \times (\text{HS} + \text{HW}) = \text{HP} \times .8 \times .746 \times (\text{HS} + \text{HW}) \\ &= \text{HP} \times (\text{HS} + \text{HW}) \times .597 \end{aligned}$$

HP = nameplate HP of constant loads.

Maintenance Run Time

- ° Savings - estimate manhours at 2 manhours per system

Enthalpy Economizer

- ° Cooling Savings - Simulation
- ° Heating Savings - None

Hot/Cold Deck Reset

- ° Cooling Savings - Simulation
- ° Heating Savings - Simulation

Chilled Water Reset

- ° Cooling Savings -

$$\begin{aligned} \text{SKWH} &= \text{Tons} \times \text{EFLH} \times 1 \text{ KWH/ton-hr.} \times \text{PEI} \times (^\circ\text{F CHW Increase}) \\ &= \text{Tons} \times 1000 \times 1 \times .015 \times 2 \\ &= \text{Tons} \times 30 \end{aligned}$$

Condenser Water Reset

- ° Cooling Savings -

$$\begin{aligned} \text{SKWH} &= \text{Tons} \times \text{EFLH} \times 1 \text{ KWH/ton-hr.} \times \text{PEI} \times (^\circ\text{F CW Decrease}) \\ &= \text{Tons} \times 1000 \times 1 \times .015 \times 3 \\ &= \text{Tons} \times 45 \end{aligned}$$

Outside Air Schedule Reset

- ° Savings -

$$\text{STHERMS} = \text{EFLH} \times \text{PECD} \times I = 1000 \times 0.01 \times I = I \times 10$$

Safety Alarms

- ° Savings - Estimate Manhours at 2 manhours per system

The following page is a system savings - cost calculation sheet with equations and constants as indicated above. This form will be used for estimating savings for each system.

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

Building No. _____

System No. _____

System Type _____

FUNCTION	SAVINGS CALCULATIONS (See _____ for Derivation of Constants)	SAVINGS			COST (Table _____)
		KW	KWH	THERMS	
Time Scheduled Operation	Cooling: _____ (cfm/MBH) x _____ (Table _____) Heating: _____ (cfm/MBH) x _____ (Table _____) Auxiliaries: _____ HP x (8760 - _____) x <u>0.597</u>	0 0 0	0	0 0 0	Basic Functions \$ _____
Duty Cycling	_____ HP x _____ Hrs x <u>0.099</u>	0		0	
Demand Limiting	_____ HP x _____ Mo. x <u>0.149</u>		0	0	
Outside Air Temp. Limit	_____ HP x (_____ + _____) Hrs x <u>0.597</u> Summer Winter	0		0	
Start/Stop Optimization	_____ HP x _____ days x <u>0.298</u>	0		0	
Run Time Recording	<u>2 man-hours/system</u>				
H/C Deck Reset	Cooling: _____ (cfm) x _____ (Table _____) Heating: _____ (cfm) x _____ (Table _____)	0 0	0	0 0	\$ _____
Enthalpy Economizer	_____ (cfm) x _____ (Table _____)	0		0	\$ _____
Chilled Water Reset	_____ Tons x <u>1000</u> FLH x <u>0.030</u>	0		0	\$ _____
Condenser Water Reset	_____ Tons x <u>1000</u> FLH x <u>0.045</u>	0		0	\$ _____
Outside Air Temp. Reset	_____ FLH x <u>10</u> THERMS (4000) x	0	0	0	\$ _____
Safety Alarms	<u>2 man-hours/system</u>	0	0	0	\$ _____
	TOTALS FOR SYSTEM				\$ _____

9.3.2 COMPUTER SIMULATION RESULTS

The computerized energy analysis results used in calculating cooling and heating savings are included on the following page. The analysis was performed using the APEC ESP-1 computer program. Example printouts from the analysis are included after the summary. Two types of buildings were analyzed, a two story, 30,000 square foot administration type building, and a one story, 80,000 square foot shop/warehouse type structure. Several occupancy and usage schedules were analyzed which represents those most prevalent at the Sample Naval Base.

COMPUTERIZED ENERGY ANALYSIS RESULTS

<u>BUILDING OCCUPANCY</u>	<u>BASE RUN #</u>	<u>BASE SYSTEM OPERATION</u>	<u>REVISED RUN #</u>	<u>REVISED SYSTEM OPERATION</u>	<u>FUEL SAVINGS GALLONS</u>	<u>ELECT SAVINGS KWH</u>	<u>HEATING UNIT SAVINGS THERM/CFM</u>	<u>COOLING UNIT SAVINGS (KWH/CFM)</u>
Admin-SZAHU	1	24 Hr	2	1 shift/5 day	8,359	40,773	0.390	1.3591
Admin-SZAHU	2	1 shift/5 day	3	1 shift/5 day w/economizer	0	8,155	0	0.2718
Admin-MZAHU	4	24 Hr	5	1 shift/5 day	25,077	122,319	1.17	4.0773
Admin-MZAHU	5	1 shift/5 day	6	1 shift/5 day w/deck reset	5,015	24,464	0.234	0.8155
Shop	9	24 Hr	10	1 shift/5 day	13,479	60,292	0.236	0.7537

Note:

SZAHU = Single zone air handling unit.

MZAHU = Multi-zone air handling unit.

EXAMPLE COMPUTERIZED ENERGY ANALYSIS SUMMARY PRINTOUTS

MASTER METER ENERGY REPORT

	ELECTRICITY		GAS		STEAM		DIESEL	
	KWH	CFH	CF	LBH	LB	GPH	GAL	
JAN	141.	22565.	1077.	331390.	0.	0.	0.	0.
FEB	147.	20452.	1212.	326261.	0.	0.	0.	0.
MAR	146.	23608.	866.	288331.	0.	0.	0.	0.
APR	161.	25579.	556.	108953.	0.	0.	0.	0.
MAY	165.	34934.	408.	45584.	0.	0.	0.	0.
JUN	167.	45206.	134.	5847.	0.	0.	0.	0.
JUL	198.	53960.	94.	583.	0.	0.	0.	0.
AUG	192.	56583.	115.	869.	0.	0.	0.	0.
SEP	171.	38144.	172.	13752.	0.	0.	0.	0.
OCT	160.	30496.	326.	50804.	0.	0.	0.	0.
NOV	140.	23337.	659.	260570.	0.	0.	0.	0.
DEC	145.	21632.	1259.	313936.	0.	0.	0.	0.
TOTAL		396518.		1716881.				

1,716,881 ft³ x 1000 BTU/ft³ = 12,378,811
138,700 BTU/gal

	OIL TYPE 1		OIL TYPE 2		COAL		TOTAL	
	GPH	GAL	GPH	GAL	LBH	LB	MBTU	
JAN	0.	0.	0.	0.	0.	0.	408402.	
FEB	0.	0.	0.	0.	0.	0.	396061.	
MAR	0.	0.	0.	0.	0.	0.	38903.	
APR	0.	0.	0.	0.	0.	0.	196253.	
MAY	0.	0.	0.	0.	0.	0.	164810.	
JUN	0.	0.	0.	0.	0.	0.	160134.	
JUL	0.	0.	0.	0.	0.	0.	184819.	
AUG	0.	0.	0.	0.	0.	0.	193986.	
SEP	0.	0.	0.	0.	0.	0.	143936.	
OCT	0.	0.	0.	0.	0.	0.	154891.	
NOV	0.	0.	0.	0.	0.	0.	340218.	
DEC	0.	0.	0.	0.	0.	0.	387765.	
TOTAL		0.		0.		0.	3070175.	

1

ENERGY SOURCE	TYPE	HEAT CONTENT	DEMAND
1	ELECTRICITY	3413.	STU/KW
2	GAS	1000.	STU/CCU FT
3	STEAM	1060.	STU/LB
4	DIESEL	134700.	BTU/GAL
5	OIL TYPE 1	138500.	BTU/GAL
6	OIL TYPE 2	152000.	BTU/GAL
7	COAL	10900.	BTU/LB

MASTER METER ENERGY REPORT

	ELECTRICITY			GAS		STEAM		DIESEL	
	KWH	CFH	CF	LBH	LBS	GPH	GAL		
JAN	141.	22452.	1409.	128074.	0.	0.	0.		
FEB	147.	19617.	1409.	105852.	0.	0.	0.		
MAR	146.	23535.	1409.	86435.	0.	0.	0.		
APR	152.	25408.	627.	22174.	0.	0.	0.		
MAY	165.	31185.	358.	4540.	0.	0.	0.		
JUN	193.	37770.	157.	332.	0.	0.	0.		
JUL	202.	41877.	0.	0.	0.	0.	0.		
AUG	195.	45216.	0.	0.	0.	0.	0.		
SEP	173.	32567.	171.	494.	0.	0.	0.		
OCT	160.	29174.	386.	8882.	0.	0.	0.		
NOV	145.	23355.	1409.	84993.	0.	0.	0.		
DEC	144.	21346.	1409.	111626.	0.	0.	0.		
TOTAL	355745.		557402.		0.				

	OIL TYPE 1			OIL TYPE 2			COAL		TOTAL	
	GPH	GAL		GPH	GAL		LBH	LBS	MBTU	
JAN	0.	0.	0.	0.	0.	0.	0.	0.	204440.	
FEB	0.	0.	0.	0.	0.	0.	0.	0.	173487.	
MAR	0.	0.	0.	0.	0.	0.	0.	0.	166762.	
APR	0.	0.	0.	0.	0.	0.	0.	0.	108890.	
MAY	0.	0.	0.	0.	0.	0.	0.	0.	117799.	
JUN	0.	0.	0.	0.	0.	0.	0.	0.	129243.	
JUL	0.	0.	0.	0.	0.	0.	0.	0.	142925.	
AUG	0.	0.	0.	0.	0.	0.	0.	0.	154329.	
SEP	0.	0.	0.	0.	0.	0.	0.	0.	111647.	
OCT	0.	0.	0.	0.	0.	0.	0.	0.	108452.	
NOV	0.	0.	0.	0.	0.	0.	0.	0.	168702.	
DEC	0.	0.	0.	0.	0.	0.	0.	0.	184480.	
TOTAL									1771556.	

$$557402 \text{ ft}^3 \times 1000 \frac{\text{BTU}}{\text{ft}^3} = 40197$$

$$138,700 \frac{\text{BTU}}{\text{gal}}$$

2

ENERGY SOURCE	TYPE	HEAT CONTENT	DEMAND
1	ELECTRICITY	3413.	BTU/KWH
2	GAS	1000.	BTU/CU FT
3	STEAM	1060.	BTU/LB
4	DIESEL	134700.	BTU/GAL
5	OIL TYPE 1	136500.	BTU/GAL
6	OIL TYPE 2	152000.	BTU/GAL
7	COAL	10900.	BTU/LB

9.4 COST ANALYSIS

The EMCS installation cost consists of central hardware and software cost, transmission system cost, building connection cost, and individual point cost.

The central hardware and software cost (along with other miscellaneous costs) are estimated as follows (using data from Section 6.0 of this report):

<u>Item</u>	<u>Cost</u>
Central Hardware:	
Central Control Unit (CCU)	\$ 25,000.
Central Communications Controller (CCC)	\$ 25,000.
Printers (2 @ \$4,000.)	\$ 8,000.
Paper Tape Reader/Punch	\$ 5,000.
Disk Storage System	\$ 20,000.
B&W CRT	\$ 3,000.
Graphic CRT	\$ 8,000.
Uninterruptable Clock	\$ 1,625.
Central Software:	
Command Software Package	\$ 30,000.
Applications Software Package	\$ 40,000.
Graphics Pages (50 @ 100)	\$ 5,000.
CCC Software Package	\$ 10,000.
Training	\$ 7,000.
Documentation	\$ 14,000.
Testing	\$ 27,000.
Shop Drawings, Supervision, etc.	\$ 30,000.
Subtotal	\$258,625.
Overhead and Profit (use 35%)	\$ 90,519.
Current Construction Cost	\$349,144.
Escalation (from Nov 1978 to bid date of Nov 1979 @ 7% per year)	\$ 24,440.
Total Estimated Bid Price (central)	\$373,584.

The building connection cost consists of the FID cost, that cost is:

FID (each)	\$ 3,000.
Overhead and Profit (use 35%)	\$ 1,050.
Current Construction Cost	\$ 4,050.
Escalation (7%)	\$ 284.
Total Estimated Bid Price (per FID)	\$ 4,334.

Point costs are those itemized in the Section 6.0 tables plus overhead and profit and escalation. Those values have been multiplied by 1.4445 (1.35×1.07) to account for these items. Point costs to perform applicable functions on different system types are tabulated on the following pages. Points required to perform each function are illustrated on the system schematics in APPENDIX B.

SYSTEM/FUNCTION POINT COSTS

<u>System Type</u>	<u>Function</u>	<u>Points Required</u>	<u>Point Cost</u>
H.W. Boiler	Run Time Record	H.W. Flow Status	\$ 199.
		Subtotal	\$ 199.
		x 1.445 =	\$ 288.
	O.A. Temp Reset	H.W.S. Temp.	\$ 216.
		H.W.R. Temp	\$ 216.
		H.W.S. Controller Reset	\$ 533.
		Subtotal	\$ 965.
		x 1.445 =	\$1,394.
	Safety Alarms	Alarm Contact Status	\$ 159.
		Subtotal	\$ 159.
		x 1.445 =	\$ 230.
Single Zone Air Handler	Basic (Note 1)	Fan Start/Stop Control	\$ 179.
		Fan Flow Status	\$ 199.
		Space Temp.	\$ 236.
		Subtotal	\$ 614.
		x 1.445 =	\$ 887.
	Enthalpy Economizer	R.A. Temp.	\$ 232.
		R.A. Humid.	\$ 346.
		Economizer Cont Interface	\$ 479.
		Subtotal	\$1,057.
		x 1.445 =	\$1,527.
Air Cooled Chiller	Basic (Note 1)	Chiller Start/Stop Control	\$ 179.
		C.W. Pump Flow Status	\$ 199.
		Subtotal	\$ 378.
		x 1.445	\$ 546.
	Chilled Wtr. Reset	C.W.S. Temp.	\$ 216.
		C.W.R. Temp.	\$ 216.
		C.W. Controller Reset	\$ 533.
		Subtotal	\$ 965.
		x 1.445	\$1,394.
	Safety Alarms	Alarm Contact Status	\$ 159.
		Subtotal	\$ 159.
		x 1.445	\$ 230.
Multizone Air Handler	Basic (Note 1)	Fan Start/Stop Control	\$ 179.
		Fan Flow Status	\$ 199.
		Space Temp.	\$ 236.
		Subtotal	\$ 614.
		x 1.445	\$ 887.

H/C Deck Reset	H. Deck Temp	\$ 255.	
	C. Deck Temp.	\$ 255.	
	H.D. Cont. Reset	\$ 533.	
	C.O. Cont. Reset	\$ 533.	
	Demand Selectors (2)	\$1,046.	
	Subtotal	\$2,622.	
	x 1.445	\$3,789.	
Stm. Boiler	Safety Alarms	Alarm Contact Status	\$ 159.
		Subtotal	\$ 159.
		x 1.445	\$ 230.
Stem. Unit	Basic (Note 1)	Valve Open/Close Interface	\$ 211.
		Space Temp.	\$ 236.
		Steam Valve	\$1,698.
		Aquastat Status	\$ 199.
		Subtotal	\$2,344.
		x 1.445	\$3,387.

SYSTEM/SAVINGS COST CALCULATION WORK SHEETS

Note: Sensors and controls used to perform certain functions may also be used to perform other functions. Duplication of cost of these devices in the analysis of each function must be avoided. On the following calculation forms, this has been accomplished by grouping functions which require the same field devices (such as time scheduled operation, duty cycling, demand limiting, etc.).

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

System Type HW Boiler

Building No. 100 System No. 1

FUNCTION	SAVINGS CALCULATIONS (See for Derivation of Constants)			SAVINGS			COST (Table)
	KW	KWH	THERMS	MF			
Time Scheduled Operation	0	0	0	0			Basic Functi \$ <u>288</u>
Duty Cycling	0		0	0			
Demand Limiting		0	0	0			
Outside Air Temp. Limit	0		0	0			
Start/Stop Optimization	0		0	0			
Run Time Recording	0	0	0	2			
H/C Deck Reset	0	0	0	0			\$
Enthalpy Economizer	0		0	0			\$
Chilled Water Reset	0		0	0			\$
Condenser Water Reset	0		0	0			\$
Outside Air Temp. Reset	0	0	75	0			\$ <u>1394</u>
Safety Alarms	0	0	0	2			\$ <u>230</u>
TOTALS FOR SYSTEM							\$ <u>1912.</u>

SYSTEM SAVINGS - COST CALCULATIONS
 Building No. 100 System No. 2 Project: Sample Naval Base
 System Type A/C CHILLER

FUNCTION	SAVINGS CALCULATIONS (See ___ for Derivation of Constants)			SAVINGS			COST (Table ___)
	KW	KWH	THERMS	TH			
Time Scheduled Operation	0	0	0	0			
Duty Cycling	0	0	0	0			
Demand Limiting	43	0	0	0			
Outside Air Temp. Limit	0	0	0	0			
Start/Stop Optimization	0	224	0	0			
Run Time Recording	0	0	0	2			
W/C Deck Reset	0	0	0	0			
Enthalpy Economizer	0	0	0	0			
Chilled Water Reset	0	0	0	0			
Condenser Water Reset	0	0	0	0			
Outside Air Temp. Reset	0	0	0	0			
Safety Alarms	0	0	0	2			
TOTALS FOR SYSTEM	43	11436	0	4			

Project: Sample Naval Base

SYSTEM SAVINGS - COST CALCULATIONS

Building No. 100 System No. 3 System Type Multistage AHU

FUNCTION	SAVINGS CALCULATIONS (See _____ for Derivation of Constants)			SAVINGS			COST (Table _____)
	KW	KWH	THERMS	MBH			
Time Scheduled Operation	0	21746	0	0			Basic Function \$ <u>887</u>
	0	0	6240	0			
	0	56058	0	0			
Duty Cycling	0	3713	0	0			
Demand Limiting	27	0	0	0			
Outside Air Temp. Limit	0		0	0			
Start/Stop Optimization	0	1118	0	0			
Run Time Recording	0	0	0	2			
H/C Deck Reset	0	0	0	0			\$ _____
Enthalpy Economize	0		0	0			\$ _____
Chilled Water Reset	0		0	0			\$ _____
Condenser Water Reset	0		0	0			\$ _____
Outside Air Temp. Reset	0	0		0			\$ _____
Safety Alarm	0	0		0			\$ _____
TOTALS FOR SYSTEM				27	82635	6240	\$ <u>987</u>

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

Building No. 200 System No. 1

System Type Steam Boiler

FUNCTION	SAVINGS CALCULATIONS (See _____ for Derivation of Constants)			SAVINGS			COST (Table _____)
	KW	KWH	THEMS	THEMS	THEMS	THEMS	
Time Scheduled Operation	0	0	0	0	0	0	Basic Function
Cooling: _____ (cfm/MBH) x _____ (Table _____)							
Heating: _____ (cfm/MBH) x _____ (Table _____)							
Auxiliaries: _____ HP x (8760 - _____) x <u>0.977</u>							
Duty Cycling	0	0	0	0	0	0	
HP x _____ Hrs x <u>0.099</u>							
Demand Limiting		0	0	0	0	0	
HP x _____ Mo. x <u>0.149</u>							
Outside Air Temp. Limit	0		0	0	0	0	
HP x (_____ + _____) Hrs x <u>0.597</u>							
Summer Winter							
Start/Stop Optimization	0		0	0	0	0	
HP x _____ days x <u>0.298</u>							
Run Time Recording							
2 man-hours/system							
H/C Check Reset	0	0	0	0	0	0	
Cooling: _____ (cfm) x _____ (Table _____)							
Heating: _____ (cfm) x _____ (Table _____)							
Enthalpy Economizer	0		0	0	0	0	
(cfm) x _____ (Table _____)							
Chilled Water Reset	0		0	0	0	0	
Tons x <u>1000</u> FLH x <u>0.030</u>							
Condenser Water Reset	0		0	0	0	0	
Tons x <u>1000</u> FLH x <u>0.045</u>							
Outside Air Temp. Reset	0		0	0	0	0	
Fltms (unit) x <u>10</u>							
Safety Alarms	0	0	0	0	0	0	
2 man-hours/system							
TOTALS FOR SYSTEM	0	0	0	0	0	0	\$ 230
	0	0	0	0	0	0	\$ 230

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

Building No. 200 System No. 2

System Type split system

FUNCTION	SAVINGS CALCULATIONS (See ___ for Derivation of Constants)		SAVINGS			COST (Table ___)
	KW	KWH	THERMS	MB		
Time Scheduled Operation	Cooling: <u>8000</u> (cfm) x <u>1.3591</u> (Table ___) Heating: <u>8000</u> (cfm) x <u>0.3902</u> (Table ___) Auxiliaries: <u>5</u> HP x (8760 - <u>2500</u>) x <u>0.597</u>	<u>3262</u> 0 <u>5606</u>	0 <u>936</u> 0	0 0 0		Basic Function \$ <u>887</u>
Duty Cycling	<u>5</u> HP x <u>2500</u> Hrs x <u>0.099</u>	0	0	0		
Demand Limiting	<u>27</u> HP x <u>6</u> Mo. x <u>0.149</u>	<u>24</u>	0	0		
Outside Air Temp. Limit	HP x (Summer + Winter) Hrs x <u>0.597</u>	0	0	0		
Start/Stop Optimization	<u>5</u> HP x <u>250</u> days x <u>0.298</u>	0	<u>373</u>	0		
Run Time Recording	<u>2 man-hours/system</u>	0	0	<u>2</u>		
H/C Deck Reset	Cooling: ___ (cfm) x ___ (Table ___) Heating: ___ (cfm) x ___ (Table ___)	0 0	0 0	0 0		\$ ___
Enthalpy Economizer	<u>8000</u> (cfm) x <u>.2718</u> (Table ___)	0	<u>2174</u>	0		\$ <u>1527</u>
Chilled Water Reset	___ Tons x <u>1000</u> FLH x <u>0.030</u>	0		0		\$ ___
Condenser Water Reset	___ Tons x <u>1000</u> FLH x <u>0.045</u>	0		0		\$ ___
Outside Air Temp. Reset	FLH x THERMS (4500) x <u>10</u>	0	0	0		\$ ___
Safety Alarms	<u>2 man-hours/system</u>	0	0	0		\$ ___
TOTALS FOR SYSTEM		<u>24</u>	<u>12653</u>	<u>936</u>	<u>2</u>	\$ <u>2414</u>

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

Building No. 300 System No. 1 System Type H.W. Boiler

FUNCTION	SAVINGS CALCULATIONS (See for Derivation of Constants)	SAVINGS			COST (Table)
		KW	KWH	THERMS	
Time Scheduled Operation	Cooling: (cfm/MBH) x (Table) Heating: (cfm/MBH) x (Table) Auxiliaries: HP x (8760 -) x <u>6.1</u> x <u>0.977</u>	0	0	0	Basic Function \$ <u>288</u>
Duty Cycling	HP x Hrs x <u>0.099</u>	0	0	0	
Demand Limiting	HP x Mo. x <u>0.149</u>		0	0	
Outside Air Temp. Limit	HP x (Summer + Winter) Hrs x <u>0.597</u>	0		0	
Start/Stop Optimization	HP x days x <u>0.298</u>	0		0	
Run Time Recording	<u>2 man-hours/system</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>2</u>
A/C Deck Reset	Cooling: (cfm) x (Table) Heating: (cfm) x (Table)	0	0	0	\$
Enthalpy Economizer	(cfm) x (Table)	0		0	\$
Chiller Water Reset	Tons x <u>1000</u> FLH x <u>0.030</u>	0		0	\$
Condenser Water Reset	Tons x <u>1000</u> FLH x <u>0.045</u>	0		0	\$
Outside Air Temp. Reset	<u>15 THERMS (start) x <u>10</u></u>	<u>0</u>	<u>0</u>	<u>150</u>	<u>0</u>
Safety Alarms	<u>2 man-hours/system</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>2</u>
TOTALS FOR SYSTEM		<u>0</u>	<u>0</u>	<u>150</u>	<u>4</u>
					<u>\$ 1394</u>
					<u>\$ 230</u>
					<u>\$ 1912</u>

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

Building No. 300 System No. 2

System Type H.W. Boiler

FUNCTION	SAVINGS CALCULATIONS (See ___ for Derivation of Constants)			SAVINGS			COST (Table ___)
	KW	KWH	TERMS	MEH			
Time Scheduled Operation	0	0	0	0	0	0	Basic Function \$ <u>288</u>
Duty Cycling	0	0	0	0	0	0	
Demand Limiting	0	0	0	0	0	0	
Outside Air Temp. Limit	0	0	0	0	0	0	
Start/Stop Optimization	0	0	0	0	0	0	
Run Time Recording	0	0	0	0	0	0	
A/C Deck Reset	0	0	0	0	0	0	\$
Enthalpy Economizer	0	0	0	0	0	0	\$
Chilled Water Reset	0	0	0	0	0	0	\$
Condenser Water Reset	0	0	0	0	0	0	\$
Outside Air Temp. Reset	0	0	0	0	0	0	\$
Safety Alarms	0	0	0	0	0	0	\$
TOTALS FOR SYSTEM	0	0	150	2	4	1912	

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

Building No. 300 System No. 3

System Type A/C CHILLER

FUNCTION	SAVINGS CALCULATIONS (See ___ for Derivation of Constants)	SAVINGS			COST (Table ___)
		KW	KWH	THERMS	
Time Scheduled Operation	Cooling: ___ (cfm/MBH) x ___ (Table ___) Heating: ___ (cfm/MBH) x ___ (Table ___) Auxiliaries: <u>19</u> HP x (8760 - <u>2500</u>) x <u>12</u> x <u>0.977</u>	0 0 0	0 <u>56058</u>	0 0 0	0 0 0
Duty Cycling	HP x ___ Hrs x <u>0.099</u>	0		0	0
Demand Limiting	<u>225</u> HP x <u>6</u> (at load) Mo. x <u>0.149</u>	<u>201</u>	0	0	0
Outside Air Temp. Limit	HP x (___ Summer + ___ Winter) Hrs x <u>0.597</u>	0		0	0
Start/Stop Optimization	<u>15</u> HP x <u>250</u> days x <u>0.298</u>	0	<u>1118</u>	0	0
Run Time Recording	<u>2 man-hours/system</u>	0	0	0	<u>2</u>
H/C Deck Reset	Cooling: ___ (cfm) x ___ (Table ___) Heating: ___ (cfm) x ___ (Table ___)	0 0	0	0	0
Enthalpy Economizer	___ (cfm) x ___ (Table ___)	0		0	0
Chilled Water Reset	<u>160</u> Tons x <u>1000</u> FLH x <u>0.030</u>	0	<u>4800</u>	0	0
Condenser Water Reset	___ Tons x <u>1000</u> FLH x <u>0.045</u>	0		0	0
Outside Air Temp. Reset	FLH x <u>10</u> THERMS (at 1000) x <u>10</u>	0	0		0
Safety Alarms	<u>2 man-hours/system</u>	0	0	0	<u>2</u>
TOTALS FOR SYSTEM		<u>201</u>	<u>61976</u>	0	0
					<u>4</u>
					\$ <u>2170</u>

Basic Function
\$ 546

Project: Sample Naval Base

SYSTEM SAVINGS - COST CALCULATIONS

Building No. 300 System No. 4

System Type single zone AHU

FUNCTION	SAVINGS CALCULATIONS (See for Derivation of Constants)		SAVINGS			COST (Table)
			KW	KWH	THERMS	
Time Scheduled Operation	Cooling: <u>30000</u> (cfm/MBH) x <u>1.3591</u> (Table)		0	<u>40773</u>	0	0
	Heating: <u>30000</u> (cfm/MBH) x <u>0.340</u> (Table)		0	0	<u>11700</u>	0
	Auxiliaries: <u>30</u> HP x (8760 - <u>2500</u>) x <u>12</u> x <u>0.597</u>		0	<u>112117</u>	0	0
Duty Cycling	NO-ABOVE 25 HRS DQ. DPT CYCLE		0		0	0
Demand Limiting	<u>30</u> HP x <u>12</u> Mo. x <u>0.149</u>		<u>54</u>	0	0	0
Outside Air Temp. Limit	HP x (Summer + Winter) Hrs x 0.597		0		0	0
Start/Stop Optimization	<u>30</u> HP x <u>250</u> days x <u>0.298</u>		0	<u>4478</u>	0	0
Run Time Recording	<u>2 man-hours/system</u>		0	0	0	<u>2</u>
H/C Back Reset	Cooling: (cfm) x (Table)		0	0	0	0
	Heating: (cfm) x (Table)		0	0	0	0
Enthalpy Economizer	<u>30000</u> (cfm) x <u>0.2718</u> (Table)		0	<u>8154</u>	0	0
Chilled Water Reset	Tons x <u>1000</u> FLH x <u>0.030</u>		0		0	0
Condenser Water Reset	Tons x <u>1000</u> FLH x <u>0.045</u>		0		0	0
Outside Air Temp. Reset	FLH x THERMS (4000) x 10		0	0		0
Safety Alarms	<u>2 man-hours/system</u>		0	0		0
TOTALS FOR SYSTEM			<u>54</u>	<u>165522</u>	<u>11700</u>	<u>2</u>
						<u>2414</u>

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

Building No. 300 System No. 5

System Type Multistage AMU

FUNCTION	SAVINGS CALCULATIONS (See _____ for Derivation of Constants)	SAVINGS				COST (Table _____)
		KW	KWH	THERMS	MH	
Time Scheduled Operation	Cooling: $18000 \text{ (cfm/MIN)} \times 4.0773 \text{ (Table)}$ Heating: $18000 \text{ (cfm/MIN)} \times 1.17 \text{ (Table)}$ Auxiliaries: $20 \text{ HP} \times (8760 - 2500) \times \frac{1}{2} \times 0.597$	0 0 0	73391 0 74744	0 21060 0	0 0 0	Basic Function \$ <u>887</u>
Duty Cycling	$20 \text{ HP} \times 2500 \text{ Hrs} \times 0.091$	0	4950	0	0	
Demand Limiting	$20 \text{ HP} \times 12 \text{ Mo.} \times 0.149$	36	0	0	0	
Outside Air Temp. Limit	$\text{HP} \times (\text{Summer} + \text{Winter}) \text{ Hrs} \times 0.597$	0		0	0	
Start/Stop Optimization	$20 \text{ HP} \times 250 \text{ days} \times 0.298$	0	1490	0	0	
Run Time Recording	$2 \text{ man-hours/system}$	0	0	0	2	
H/C Deck Reset	Cooling: $18000 \text{ (cfm)} \times 0.8155 \text{ (Table)}$ Heating: $18000 \text{ (cfm)} \times 0.234 \text{ (Table)}$	0 0	14679 0	0 4212	0 0	\$ <u>3789</u>
Inthalpy Economizer	$\text{_____ (cfm)} \times \text{_____ (Table)}$	0		0	0	\$ _____
Chilled Water Reset	$\text{_____ Tons} \times 1000 \text{ FLH} \times 0.030$	0		0	0	\$ _____
Condenser Water Reset	$\text{_____ Tons} \times 1000 \text{ FLH} \times 0.045$	0		0	0	\$ _____
Outside Air Temp. Reset	$\text{_____ FLH} \times \text{_____ THERMS (4000)} \times 10$	0	0		0	\$ _____
Safety Alarms	$2 \text{ man-hours/system}$	0	0		0	\$ _____
TOTALS FOR SYSTEM		36	169254	25272	2	\$ <u>4676</u>

SYSTEM SAVINGS - COST CALCULATIONS

Building No. 300 System No. 6 Project: Sample Naval Base

System Type Multistage AHU

FUNCTION	SAVINGS CALCULATIONS (See _____ for Derivation of Constants)	SAVINGS			COST (Table _____)
		KW	KWH	THERMS	
Time Scheduled Operation	Cooling: $20000 \text{ (cfm/MBH)} \times 4.0733 \text{ (Table)}$ Heating: $20000 \text{ (cfm/MBH)} \times 4.17 \text{ (Table)}$ Auxiliaries: $30 \text{ HP} \times (8760 - 2500) \times 12 \times 0.977$	0	81466	23400	Basic Function: \$ <u>887</u>
Duct Cooling	HP x _____ Hrs x <u>0.099</u>	0	112117	0	
Demand Limiting	<u>30</u> HP x <u>12</u> Mo. x <u>0.149</u>	54	0	0	
Outside Air Temp. Limit	HP x (_____ + _____) Hrs x <u>0.597</u> Summer Winter	0		0	
Start/Stop Optimization	<u>30</u> HP x <u>250</u> days x <u>0.298</u>	0	2235	0	
Run Time Recording	<u>2 man-hours/system</u>	0	0	0	2
H/C Deck Reset	Cooling: $20000 \text{ (cfm)} \times 0.8155 \text{ (Table)}$ Heating: $20000 \text{ (cfm)} \times 0.234 \text{ (Table)}$	0	16310	0	\$ <u>3789</u>
Enthalpy Economizer	_____ (cfm) x _____ (Table _____)	0		0	
Chilled Water Reset	_____ Tons x <u>1000</u> FLH x <u>0.030</u>	0		0	
Condenser Water Reset	_____ Tons x <u>1000</u> FLH x <u>0.045</u>	0		0	
Outside Air Temp. Reset	_____ THERMS (40000) x <u>10</u>	0	0		
Safety Alarms	<u>2 man-hours/system</u>	0	0		
TOTALS FOR SYSTEM		54	212128	28080	2 \$ <u>4676</u>

Project: Sample Naval Base

SYSTEM SAVINGS - COST CALCULATIONS

Building No. 400 System No. 1 System Type Stm Boiler

FUNCTION	SAVINGS CALCULATIONS (See _____ for Derivation of Constants)			SAVINGS			COST (Table _____)
	KW	KWH	THERMS	MH			
Time Scheduled Operation	0	0	0	0			Basic Functi \$ _____
Duty Cycling	0	0	0	0			
Demand Limiting		0	0	0			
Outside Air Temp. Limit	0		0	0			
Start/Stop Optimization	0		0	0			
Run Time Recording							
H/C Deck Reset	0	0	0	0			\$ _____
Enthalpy Economizer	0		0	0			\$ _____
Chilled Water Reset	0		0	0			\$ _____
Condenser Water Reset	0		0	0			\$ _____
Outside Air Temp. Reset	0	0		0			\$ _____
Safety Alarms	0	0	0	2			\$ <u>230</u>
TOTALS FOR SYSTEM							\$ <u>230</u>

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

System Type Steam Unit Heaters

System No. 2

Building No. 400

SAVINGS CALCULATIONS
(See ___ for Derivation of Constants)

FUNCTION	SAVINGS CALCULATIONS (See ___ for Derivation of Constants)	SAVINGS			COST (Table ___)
		KW	KWH	THERMS	
Time Scheduled Operation	Cooling: (cfm/MBH) x (Table ___) Heating: <u>64815</u> (cfm/MBH) x <u>0.236</u> (Table ___) Auxiliaries: HP x (8760 - ___) x <u>0.597</u> x <u>0.597</u>	0 0 0	0	0 <u>15296</u> 0	Basic Function \$ <u>3387</u>
Duty Cycling	HP x ___ Hrs x <u>0.099</u>	0		0	
Demand Limiting	HP x ___ Mo. x <u>0.149</u>		0	0	
Outside Air Temp. Limit	HP x (___ + ___) Hrs x <u>0.597</u> Summer Winter	0		0	
Start/Stop Optimization	HP x ___ days x <u>0.298</u>	0		0	
Run Time Recording	<u>2 man-hours/system</u>				
H/C Deck Reset	Cooling: ___ (cfm) x ___ (Table ___) Heating: ___ (cfm) x ___ (Table ___)	0 0	0	0 0	\$ ___
Enthalpy Economizer	___ (cfm) x ___ (Table ___)	0		0	\$ ___
Chilled Water Reset	Tons x <u>1000</u> FLH x <u>0.030</u>	0		0	\$ ___
Condenser Water Reset	Tons x <u>1000</u> FLH x <u>0.045</u>	0		0	\$ ___
Outside Air Temp. Reset	FLH THERMS (4800) x <u>10</u>	0	0	0	\$ ___
Safety Alarms	<u>2 man-hours/system</u>	0	0		\$ ___
TOTALS FOR SYSTEM		0	0	<u>15296</u>	\$ <u>3387</u>

Project: Sample Naval Base

SYSTEM SAVINGS - COST CALCULATIONS

Building No. 500 System No. 1

System Type Split System

FUNCTION	SAVINGS CALCULATIONS (See ___ for Derivation of Constants)			SAVINGS			COST (Table ___)
	KW	KWH	THERMS	MH			
Time Scheduled Operation	Cooling: <u>15000</u> (cfm/MBH) x <u>1.391</u> (Table ___) Heating: <u>15000</u> (cfm/MBH) x <u>0.390</u> (Table ___) Auxiliaries: <u>20</u> HP x (8760 - <u>2500</u>) x <u>1.2</u> x <u>0.917</u>	<u>20387</u> <u>0</u> <u>74744</u>	<u>0</u> <u>5850</u> <u>0</u>	<u>0</u> <u>0</u> <u>0</u>			Basic Function \$ <u>887</u>
Duty Cycling	<u>20</u> HP x <u>2500</u> Hrs x <u>0.091</u>	<u>4950</u>	<u>0</u>	<u>0</u>			
Demand Limiting	<u>63</u> HP x <u>6</u> Mo. x <u>0.149</u>	<u>0</u>	<u>0</u>	<u>0</u>			
Outside Air Temp. Limit	HP x (___ Summer + ___ Winter) Hrs x <u>0.597</u>	<u>0</u>	<u>0</u>	<u>0</u>			
Start/Stop Optimization	<u>20</u> HP x <u>250</u> days x <u>0.298</u>	<u>1490</u>	<u>0</u>	<u>0</u>			
Run Time Recording	<u>2 man-hours/system</u>	<u>0</u>	<u>0</u>	<u>2</u>			
H/C Deck Reset	Cooling: ___ (cfm) x ___ (Table ___) Heating: ___ (cfm) x ___ (Table ___)	<u>0</u> <u>0</u>	<u>0</u>	<u>0</u> <u>0</u>		\$ ___	
Enthalpy Economizer	___ (cfm) x ___ (Table ___)	<u>0</u>	<u>0</u>	<u>0</u>		\$ ___	
Chilled Water Reset	Tons x <u>1000</u> FLH x <u>0.030</u>	<u>0</u>	<u>0</u>	<u>0</u>		\$ ___	
Condenser Water Reset	Tons x <u>1000</u> FLH x <u>0.045</u>	<u>0</u>	<u>0</u>	<u>0</u>		\$ ___	
Outside Air Temp. Reset	FLH <u>2 man-hours/system</u> <u>10</u> THERMS (4000) x	<u>0</u>	<u>0</u>	<u>0</u>		\$ ___	
Safety Alarms	<u>2 man-hours/system</u>	<u>0</u>	<u>0</u>	<u>0</u>		\$ ___	
TOTALS FOR SYSTEM		<u>56</u>	<u>101571</u>	<u>5950</u>	<u>2</u>	\$ <u>887</u>	

SYSTEM SAVINGS - COST CALCULATIONS

Project: Sample Naval Base

Building No. 500 System No. 2

System Type HW Boiler

FUNCTION	SAVINGS CALCULATIONS (See _____ for Derivation of Constants)			SAVINGS			COST (Table _____)
	KW	KWH	THEMS	THEMS	MH		
Time Scheduled Operation	Cooling: _____ (cfm/MBH) x _____ (Table _____) Heating: _____ (cfm/MBH) x _____ (Table _____) Auxiliaries: _____ HP x (8760 - _____) x <u>0.597</u>						Basic Function \$ <u>288</u>
Duty Cycling	_____ HP x _____ Hrs x <u>0.099</u>						
Demand Limiting	_____ HP x _____ Mo. x <u>0.149</u>						
Outside Air Temp. Limit	_____ HP x (_____ + _____) Hrs x <u>0.597</u> Summer Winter						
Start/Stop Optimization	_____ HP x _____ days x <u>0.298</u>						
Run Time Recording	<u>2 man-hours/system</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>2</u>		
H/C Deck Reset	Cooling: _____ (cfm) x _____ (Table _____) Heating: _____ (cfm) x _____ (Table _____)	0	0	0	0	\$ _____	
Enthalpy Economizer	_____ (cfm) x _____ (Table _____)	0	0	0	0	\$ _____	
Chilled Water Reset	_____ Tons x <u>1000</u> FLH x <u>0.030</u>	0	0	0	0	\$ _____	
Condenser Water Reset	_____ Tons x <u>1000</u> FLH x <u>0.045</u>	0	0	0	0	\$ _____	
Outside Air Temp. Reset	<u>_____ Tons x <u>6</u> <u>THEMS</u> (<u>MBH</u>) x <u>10</u></u>	<u>0</u>	<u>0</u>	<u>60</u>	<u>0</u>	<u>\$ 1394</u>	
Safety Alarms	<u>2 man-hours/system</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>2</u>	<u>\$ 230</u>	
TOTALS FOR SYSTEM							<u>\$ 1912</u>

BUILDING SAVINGS - COST SUMMARY

Building # 100

SYSTEM NO.	SYSTEM TYPE	SAVINGS				COST
		KW	KWH	THERMS	MH	
1	H.W. Boiler	0	0	75	4	1912
2	A/C Chiller	43	11436	0	4	776
3	ME AHU	27	82635	6240	2	887
TOTALS		70	94071	6315	10	3575
		BUILDING CONNECT COST				4334
		TOTAL COST				7909

$$\text{ENERGY SAVINGS} = \frac{(\text{94071 KWH} \times 11,600) + (\text{6315 THERMS} \times 100,000)}{1,000,000 \text{ BTU/MBTU}} = \text{1723 MBTU}$$

$$\text{\$ SAVINGS} = \left(\frac{70}{\text{KW}} \times \$ \frac{4.00}{\text{KW}} \right) + \left(\frac{94071}{\text{KWH}} \times \$ \frac{.03}{\text{KWH}} \right) + \left(\frac{6345}{\text{THERMS}} \times \$ \frac{.40}{\text{THERM}} \right) + \left(\frac{10}{\text{MH}} \times \$ \frac{10}{\text{MH}} \right) = \$ \underline{5728}$$

E/C RATIO = 218

BUILDING SAVINGS - COST SUMMARY

Building # 200

SYSTEM NO.	SYSTEM TYPE	SAVINGS				COST
		KW	KWH	THERMS	MH	
1	Stm. Boiler	0	0	0	2	230
2	Split Sys.	24	12653	936	2	2414
TOTALS		24	12653	936	4	2644
		BUILDING CONNECT COST				4334
		TOTAL COST				6978

$$\text{ENERGY SAVINGS} = \frac{(12653 \text{ KWH} \times 11,600) + (936 \text{ THERMS} \times 100,000)}{1,000,000 \text{ BTU/MBTU}} = 240 \text{ MBTU}$$

$$\text{\$ SAVINGS} = (24 \text{ KW} \times \$4.00/\text{KW}) + (12653 \text{ KWH} \times \$0.03/\text{KWH}) \\ + (936 \text{ THERMS} \times \$0.40/\text{THERM}) + (4 \text{ MH} \times \$10/\text{MH}) = \$890$$

E/C RATIO = 34

1970	10	1000	1000	1000	1000
1971	10	1000	1000	1000	1000
1972	10	1000	1000	1000	1000
1973	10	1000	1000	1000	1000
1974	10	1000	1000	1000	1000
1975	10	1000	1000	1000	1000
1976	10	1000	1000	1000	1000
1977	10	1000	1000	1000	1000
1978	10	1000	1000	1000	1000
1979	10	1000	1000	1000	1000
1980	10	1000	1000	1000	1000

9.5 BUILDING SAVINGS-COST SUMMARY SHEETS

1970	10	1000	1000	1000	1000
1971	10	1000	1000	1000	1000
1972	10	1000	1000	1000	1000
1973	10	1000	1000	1000	1000
1974	10	1000	1000	1000	1000
1975	10	1000	1000	1000	1000
1976	10	1000	1000	1000	1000
1977	10	1000	1000	1000	1000
1978	10	1000	1000	1000	1000
1979	10	1000	1000	1000	1000
1980	10	1000	1000	1000	1000

BUILDING SAVINGS - COST SUMMARY

Building # 300

SYSTEM NO.	SYSTEM TYPE	SAVINGS				COST
		KW	KWH	THERMS	MH	
<u>1</u>	<u>H.W. Boiler</u>	<u>0</u>	<u>0</u>	<u>150</u>	<u>4</u>	<u>1912</u>
<u>2</u>	<u>H.W. Boiler</u>	<u>0</u>	<u>0</u>	<u>150</u>	<u>4</u>	<u>1912</u>
<u>3</u>	<u>A/C Chiller</u>	<u>201</u>	<u>61976</u>	<u>0</u>	<u>4</u>	<u>2170</u>
<u>4</u>	<u>SE AHU</u>	<u>54</u>	<u>165522</u>	<u>11700</u>	<u>2</u>	<u>2414</u>
<u>5</u>	<u>MZ AHU</u>	<u>36</u>	<u>169254</u>	<u>25272</u>	<u>2</u>	<u>4676</u>
<u>6</u>	<u>MZ AHU</u>	<u>54</u>	<u>212128</u>	<u>28080</u>	<u>2</u>	<u>4676</u>
TOTALS		<u>345</u>	<u>608880</u>	<u>65352</u>	<u>18</u>	<u>17760</u>
BUILDING CONNECT COST						<u>4334</u>
TOTAL COST						<u>22094</u>

$$\text{ENERGY SAVINGS} = \frac{(\underline{608880} \text{ KWH} \times 11,600) + (\underline{65352} \text{ THERMS} \times 100,000)}{1,000,000 \text{ BTU/MBTU}} = \underline{7241} \text{ MBTU}$$

$$\text{\$ SAVINGS} = (\underline{345} \text{ KW} \times \$ \underline{4.00} / \text{KW}) + (\underline{608880} \text{ KWH} \times \$ \underline{.03} / \text{KWH}) + (\underline{65352} \text{ THERMS} \times \$ \underline{.40} / \text{THERM}) + (\underline{18} \text{ MH} \times \$ \underline{10} / \text{MH}) = \$ \underline{45967}$$

$$\text{E/C RATIO} = \underline{328}$$

Building # 400

$$\text{ENERGY SAVINGS} = \frac{(\text{0 KWH} \times 11,600) + (\text{15296 THERMS} \times 100,000)}{1,000,000 \text{ BTU/MBTU}} = \text{1530 MBTU}$$

E/C RATIO = 192

AD-A073 419

CIVIL ENGINEERING LAB (NAVY) PORT HUENEME CA

F/G 5/1

ENERGY MONITORING AND CONTROL SYSTEM (EMCS). ECONOMIC ANALYSIS --ETC(U)

FEB 79

UNCLASSIFIED

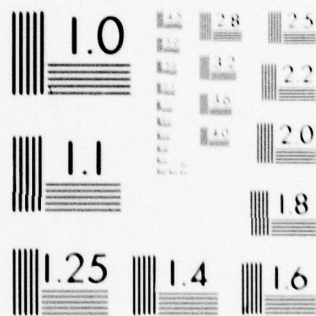
NL

2 OF 2

AD
A073419



END
DATE
FILMED
10-79
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Building # 500

$$\text{ENERGY SAVINGS} = \frac{(101571 \text{ KWH} \times 11,600) + (5910 \text{ THERMS} \times 100,000)}{1,000,000 \text{ BTU/MBTU}} = 1769 \text{ MBTU}$$

E/C RATIO = **248**

9.6 PRIORITIZED BUILDING LIST

PRIORITIZED BUILDING LIST

[illegible]

— cutoffs
line for
budget =
420,000

Totals above

9.7 ECIP ECONOMIC ANALYSIS SUMMARY

ECIP ECONOMIC ANALYSIS SUMMARY

ACTIVITY & LOCATION Norfolk, Va. P- 001
 TITLE OF PROJECT Sample Naval Base FY- 80

INVESTMENT

1. PROJECT COSTS (Economic life of 15 years)
 - a. Project cost escalated to end of program year.... \$ 420,000
 - b. Design costs not yet obligated \$ 25,200
 - c. Total Project Cost (a + b) \$ 445,200

SAVINGS

2. ANNUAL ELECTRICITY SAVINGS: KWH: 710,451
 - a. Equivalent energy: KWH x 0.0116 (MBTU's: \$ 8241)
 - b. Cost per KWH at end of program year \$ 0.04
 - c. First year annual dollar savings (KWH x b) \$ 28418
 - d. Differential escalation present worth factor 12.278
 - e. Discounted savings (c x d) \$ 348916
3. ANNUAL ENERGY SAVINGS (TYPE: Oil MBTU's: 9287)
 - a. Cost per MBTU at end of program year \$ 5.38
 - b. First year annual dollar savings \$ 49964
 - c. Differential escalation present worth factor 13.112
 - d. Discounted savings (b x c) \$ 655128
4. ANNUAL ENERGY SAVINGS (TYPE: Elec Demand MBTU's: 471 kw)
 - a. Cost per ~~unit~~ at end of program year \$ 5.38
 - b. First year annual dollar savings \$ 2534
 - c. Differential escalation present worth factor 12.278
 - d. Discounted savings (b x c) \$ 31112
5. ANNUAL OTHER-THAN-ENERGY SAVINGS (OR COSTS)
 - a. Labor (36 mh. x 11.30) \$ 407
 - b. Material & Other (Op. & Maint.: 10% of const.) \$ (42000)
 - c. Total (a + b) \$ (41593)
 - d. 10% Discount Factor 7.980
 - e. Discounted Other-than-energy savings (or costs) . \$ (331,912)
6. TOTAL FIRST YEAR ANNUAL SAVINGS (2c + 3b + 4b + 5c) .. \$ 39,323
7. TOTAL DISCOUNTED SAVINGS (2e + 3d + 4d + 5e) \$ 703,244

COST ESCALATION

			<u>79</u>	<u>80</u>					
Current	Elec	\$.03	x	1.16	x	1.16	x		= \$ 0.04
rates	Oil	\$.40	x	1.16	x	1.16	x		= \$ 0.538/therm = \$ 5.38/MBTU
as of	Labor	\$ 10.00	x	1.064	x	1.062	x		= \$ 11.30
10/78	Demur	\$ 4.00	x	1.16	x	1.16	x		= \$ 5.38

RATIOS

8. DISCOUNTED SAVINGS/INVESTMENT RATIO (Line 7 + 1c) 1.58
9. TOTAL MBTU SAVINGS 17528 + (Line 1a + 1000) 41.7
10. SIMPLE PAYBACK PERIOD (1a + Line 6) 10.7 YRS

NOTE: For ETAP projects use line 1c in lines 9 and 10 in lieu of 1a.
 97.

APPENDIX

APPENDIX A - FUNCTION IDENTIFICATION

As stated previously, an EMCS function is defined as a specific independent operational capability. An EMCS can perform many different functions. It can be programmed to monitor, regulate, and control almost an infinite number of tasks. The same tasks may also be accomplished in an infinite number of ways. The identification used for a particular function varies with the individual EMCS manufacturers and their methods and approach to a particular function may also vary. This variation generally depends on the particular software or hardware a manufacturer uses to accomplish each function, rather than the function itself. Therefore, it is possible to identify individual functions the EMCS can perform. The following paragraphs identify the EMCS functions considered in this study. These represent the most common functions available from EMCS manufacturers today. Additional functions exist and may provide some additional energy and manpower savings, however, those listed will most certainly provide the bulk of these savings.

The following paragraphs describe each function considered in this study.

TIME SCHEDULED OPERATION

Time scheduled operation consists of the starting and stopping of a system based on the time and type of day. Type of day refers to weekdays, Saturdays, Sundays, holidays, or any other day which has a different schedule of operation. This is the simplest of all EMCS functions to install, maintain, and operate. It also provides the greatest potential for energy conservation if systems are currently being operated unnecessarily during unoccupied hours. HVAC systems connected to the EMCS generally include a temperature sensor in a space which prompts the EMCS to override the shutoff if the temperature drops below a certain level.

DUTY CYCLING

Duty cycling consists of the shutdown of a system for predetermined short periods of time during normal operating hours. This function is normally only applicable to heating, ventilating, and air conditioning systems. Its operation is based on the theory that HVAC systems seldom operate at peak output, thus if the system is shut off for a short period of time, it has enough capacity to overcome the slight temperature drift which occurs during this shutdown. Although the interruption does not reduce the net space heating or cooling energy, it does reduce energy input to constant auxiliary loads such as fans and pumps. This function also reduces outside air heating and cooling loads since the outside air intake damper is closed while an air handling unit is off. Systems are generally cycled off for some fixed period of time, say 15 minutes, out of each hour of operation. The off period time length and its frequency should be adjustable. The off period time length is normally adjusted for a longer duration during moderate seasons and shorter duration during peak seasons. Duty cycling does produce additional wear on belts and motor starting circuits. Further, it may affect building air balance between building zones. Awareness of these problems may preclude use of this function in certain cases.

DEMAND LIMITING START/STOP

This function consists of the stopping of electrical loads to prevent setting a high electrical demand peak and thus increasing electrical costs where demand oriented rate schedules apply. There are many complex schemes for accomplishing this function. They all generally monitor the base electrical demand continuously. Based on the monitored data, demand predictions are made by the EMCS. When these predictions exceed preset limits, certain scheduled electrical loads are shut off by the EMCS to reduce the rate of consumption and the predicted peak demand. Additional loads are turned off on a priority basis if the initial load shed action does not reduce the predicted demand enough to satisfy the function requirements. Generally, the loads to be shed are HVAC items. The reasoning used in the Duty Cycling discussion holds here also: allow a slight temperature drift in the space by shutting off the HVAC equipment. Utility rate schedules, which include "time of day" pricing, offer additional savings opportunities. Running of certain equipment, such as water well pumps, during off peak hours has significant impact under that type of schedule and should be thoroughly investigated.

OUTSIDE AIR TEMPERATURE LIMIT SHUTOFF

An Outside Air Temperature Limit Shutdown function provides the capability to automatically shut off or disable designated control points based on seasonally dependent designated outside air temperature limits. The EMCS disables or shuts off control points automatically if the outside air temperature rises above a preset value (WINTER mode of operation) or drops below a preset value (SUMMER mode of operation). The control point is restarted or reenabled whenever the outside air temperature drops below the preset value (WINTER) minus an adjustable differential or rises above the preset value (SUMMER) plus an adjustable differential. The current mode (SUMMER or WINTER) is defined and altered manually by the operator.

ENTHALPY ECONOMIZER

The utilization of an all outside air economizer cycle can be a cost effective energy conservation measure, depending on the climatic conditions and the type of mechanical system. Where applicable, the cycle uses outside air to satisfy all or a portion of the building's cooling requirements when the enthalpy or total heat content of the outside air is less than that of the return air from the space. Outside air is introduced through the mechanical system and relieved during this cycle in lieu of the normal recirculation system.

HOT/COLD DECK TEMPERATURE RESET

Mechanical systems such as dual duct systems and some multizone systems use a parallel arrangement of heating and cooling surfaces commonly referred to as hot and cold deck surfaces for the purposes of providing heating and cooling mediums simultaneously. Generally speaking, both heated and cooled air streams are mixed to satisfy the individual space thermal requirements.

In the absence of optimization controls, these systems can waste energy because the final space control merely mixes the two air streams to produce the desired result. While the space conditions may be acceptable, the greater the difference between the temperatures of the two streams, the more inefficiently the system will operate. This function can select the individual areas with the greatest heating and cooling requirements, establish the necessary hot deck and cold deck temperatures based on these extremes, and minimize the inefficiency of the system.

A variation of the hot and cold deck multizone system is the system equipped with a cold deck and a bypass section at the mechanical system and individual heating coils in the reheat position downstream from the unit. The system operates with a constant cold deck temperature which is, in turn, mixed with the bypass air in an effort to satisfy individual zone requirements. Air supplied at temperatures below the individual space temperature requirements is elevated in temperature by the reheat coil in response to signals from an individual space thermostat. Selection of the space with the greatest cooling requirements and resetting the cold deck discharge temperature in response to these requirements minimizes the energy used for reheat.

CHILLED WATER TEMPERATURE RESET

The energy required to generate chilled water in a reciprocating or centrifugal electric driven refrigeration machine is a function of a number of parameters including the temperature of the chilled water leaving the machine. Because the refrigerant suction temperature is a direct function of the leaving water temperature, the higher the two temperatures, the lower the energy input per ton of refrigeration. As a result, because chilled water temperatures are selected for peak design times, in the absence of strict humidity control requirements, most chilled water temperatures can be elevated during most operating hours. Depending on the operating hours, size of the equipment, and configuration of the system, energy savings can be effected by resetting the chilled water. The chilled water temperature can be elevated to satisfy the greatest cooling requirements. Generally, this determination is made by the position of the chilled water valves on the various cooling systems. The positions of the control devices supplying the various cooling coils are monitored and the chilled water temperature is elevated until at least one control device is in the maximum position. Other control schemes may be necessary to satisfy different system configurations.

CONDENSER WATER TEMPERATURE RESET

Another parameter affecting the energy input to a refrigeration system is the temperature of the condenser water entering the machine. Conventionally, heat rejection equipment is designed to produce a specified condenser water temperature such as 85° at peak wet bulb temperatures. In many instances, automatic controls are provided to maintain a specified temperature at conditions other than peak design. To optimize the performance of the condenser water system, however, this system can be reset when outdoor wet bulb temperatures will produce lower condenser water temperature.

Where applicable, this function will reduce the energy input to the refrigeration machine.

OUTSIDE AIR TEMPERATURE RESET SCHEDULE

Hot water heating systems, whether the hot water is supplied by a boiler or a converter, are designed to supply the heating requirements for the system at outdoor design temperatures. Frequently, depending on the specific system design, the hot water supply temperature can be reduced as the heating requirements for the facility are reduced. For most facilities, this reduction in heating requirements is directly related to an increase in outdoor ambient temperature. Where applicable, the capability to reduce the temperature of the supply water as a function of outdoor temperature will effect operating savings. To accomplish this function, the temperature controller for the hot water supply is reset on a predetermined schedule as a function of outdoor temperature.

START/STOP OPTIMIZATION

An additional feature of the time scheduled operation of mechanical systems described above is the optimized start/stop feature available from the system. Mechanical systems serving areas that are not occupied 24 hours a day should be shut down during the unoccupied hours. Traditionally, the systems are restarted before occupancy in order to cool down or heat up the space. Normally this function is performed on a fixed schedule independent of weather, space conditions, etc. The optimized start/stop feature of the system automatically starts and stops the system to minimize the energy required to provide the desired environmental conditions during occupied hours. The function automatically evaluates the thermal inertia of the structure, the capacity of the system to either increase or reduce temperatures in the facility, start-up and shut-down times, and weather conditions to accurately determine the minimum hours of operation of the HVAC system to satisfy the thermal requirements of the building.

BOILER PROFILE AND SELECT

In certain application of multi-boiler central heating plants, there is the opportunity to optimize the boiler plant by selecting the most efficient equipment to satisfy the instantaneous heating requirement. By monitoring fuel input as a function of the output, profiles can be developed for each of the units in a central plant. Based on the operating history developed, and the loads, plant operation can be optimized to minimize energy input.

CHILLER PROFILE AND SELECT

This function is very similar to the boiler profile described above. Operating data is obtained and compared with the predicted operating characteristics of each individual machine prepared by the manufacturer. Based on the operating data for each machine with the energy input requirements for each operating condition and the instantaneous load, the function would

select the chiller or chillers required to meet the load with the minimum energy input.

MAINTENANCE RUN TIME REPORTS:

A number of maintenance functions associated with mechanical equipment are related to or can be related to the number of operating hours of the specific item of equipment. Some of these functions include lubrication, cleaning, bearing checks, etc.

SAFETY ALARMS:

Many items of mechanical equipment are provided with various types of alarms for both personnel and equipment protection. Alarms such as high and low water for boilers, gas pressure alarms, and various temperature and pressure alarms on refrigeration machines, are typical of the types of functions that can be monitored. Monitoring of such alarms provides the console operator with information regarding the failure of equipment or the development of potential problems with the system operation.


















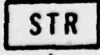

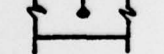
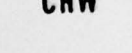

INTERCOM:

A function of the system that can be beneficial from a maintenance standpoint is the capability of communicating between the operators console, the field interface devices or other remote intercom station locations. The system can be used for intercommunication between maintenance personnel and console operator for a check out of the overall system, and for monitoring of start up of equipment.

APPENDIX B - SYSTEM SCHEMATICS

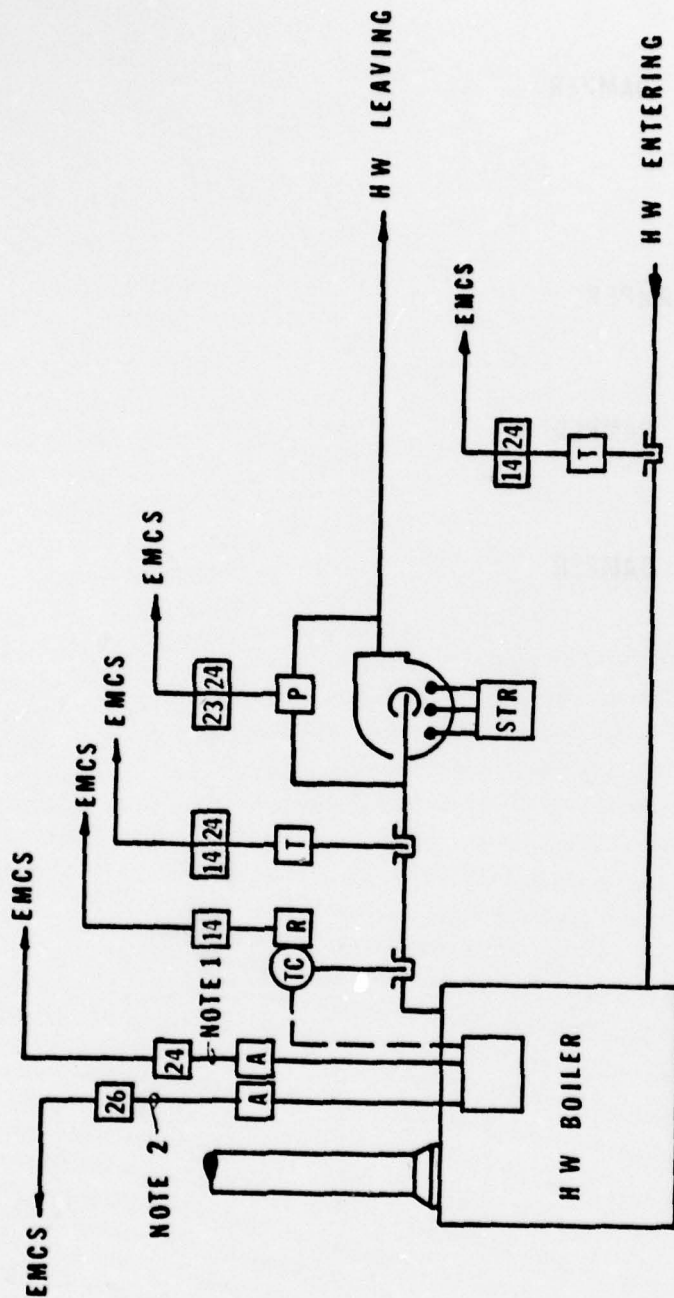
On the following pages find simplified schematics of common mechanical systems to which an EMCS may be applicable. EMCS functions commonly performed along with the sensors and controls required for each function are indicated for each schematic.

SYMBOLS

	EMCS	SIGNAL TRANSMITTED TO EMCS
	EMCS	SIGNAL RECEIVED FROM EMCS
	A	ALARM CONTACT SIGNAL
	C	GREATEST COOLING DEMAND SIGNAL
	E	ENTHALPY ECONOMIZER CONTROL INTERFACE
	H	GREATEST HEATING DEMAND SIGNAL
	I	LOCAL CONTROL INTERRUPTION INTERFACE
	L	PRESSURE INDICATION SIGNAL
	O	ON/OFF STATUS SIGNAL
	P	DIFFERENTIAL PRESSURE SWITCH STATUS SIGNAL
	R	CONTROLLER RESET INTERFACE
	S	START/STOP INTERFACE
	T	TEMPERATURE INDICATION
	W	HUMIDITY INDICATION SIGNAL
	14	FUNCTION NUMBER WHICH REQUIRES SIGNAL
	TC	TEMPERATURE CONTROLLER
	PC	PRESSURE CONTROLLER
	DS	HIGH/LOW DEMAND SIGNAL SELECTOR
	STR	MOTOR STARTER
		SENSOR INSTALLED IN THERMOMETER WELL
		SENSOR INSTALLED IN DUCT OR PLENUM
	CHW	CHILLED WATER

SYMBOLS CONTINUED

EA	EXHAUST AIR
EAD	EXHAUST AIR DAMPER
HW	HOT WATER
MA	MIXED AIR
MZD	MULTIZONE DAMPER
OA	OUTSIDE AIR
OAD	OUTSIDE AIR DAMPER
RA	RETURN AIR
RAD	RETURN AIR DAMPER
SA	SUPPLY AIR



NOTES:

1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNALS TO THE EMCS FOR EACH OF FOLLOWING SAFETY DEVICES

LOW WATER CUTOFF

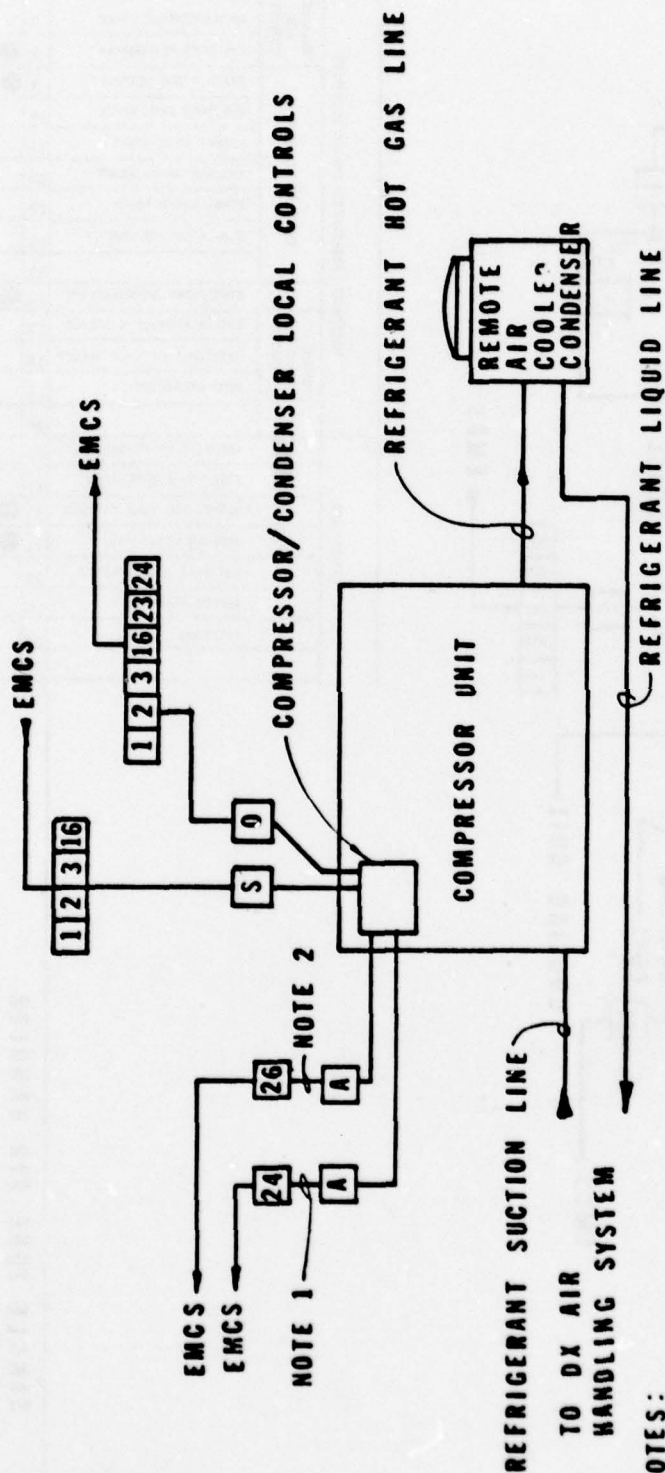
FLAME SAFETY CUTOFF

HI TEMPERATURE CUTOFF

2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF THE ABOVE LISTED SAFETY DEVICES TRIP.

HOT WATER BOILER

EQUIPMENT CH/OT	DEMAND LIMITING	TIME SCHEDULED OPERATION	1
		DUTY CYCLING	2
		START/STOP	3
		GENERATOR OPERATION	4
		CHILLER LIMIT ADJUST	5
			6
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7
		ENTHALPY ECONOMIZER	8
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9
		NOT/COLD DECK RESET	10
		REHEAT COIL RESET	11
		CHILLED WATER RESET	12
		COND. WATER RESET	13
		O.A. SCHEDULE RESET	14
			15
		CENTRAL PLANT OPTIMIZATION	START/STOP OPTIMIZATION
	BOILER PROFILE & SELECT		17
	CHILLER PROFILE & SELECT		18
	PUMP SELECTION		19
			20
	MONITORING	SECURITY FUNCTIONS	21
FIRE ALARM FUNCTIONS		22	
MAINT. RUN TIME REPORTS		23	
TROUBLE DIAGNOSIS		24	
CRITICAL AREAS ALARMS		25	
SAFETY ALARMS		26	
INTERCOM		27	
	28		



NOTES:

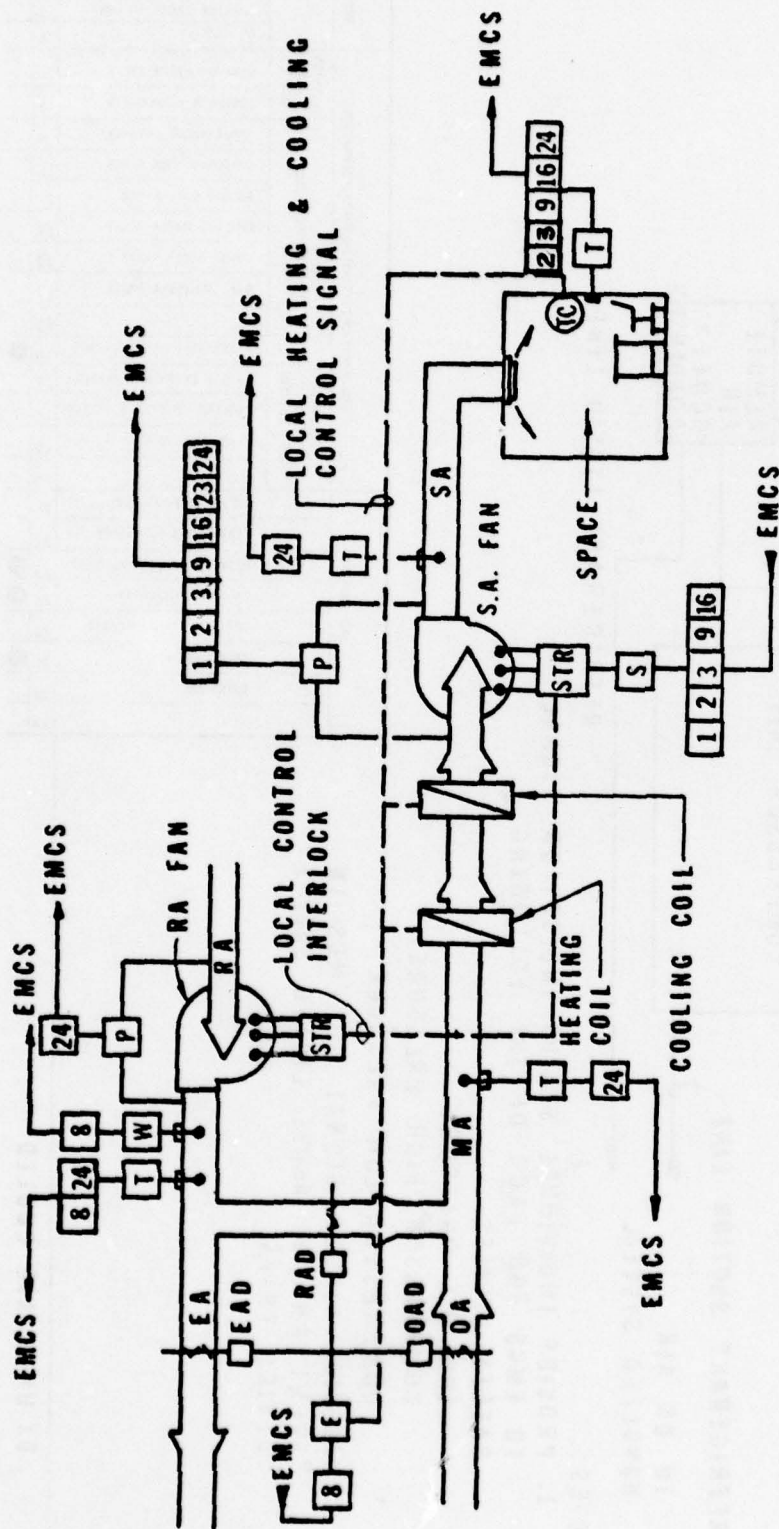
1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNAL TO EMCS FOR EACH OF THE FOLLOWING SAFETY DEVICES:

- LOW OIL PRESSURE
- COMPRESSOR HIGH PRESSURE
- COMPRESSOR LOW PRESSURE

2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF ABOVE LISTED SAFETY DEVICES TRIPS.

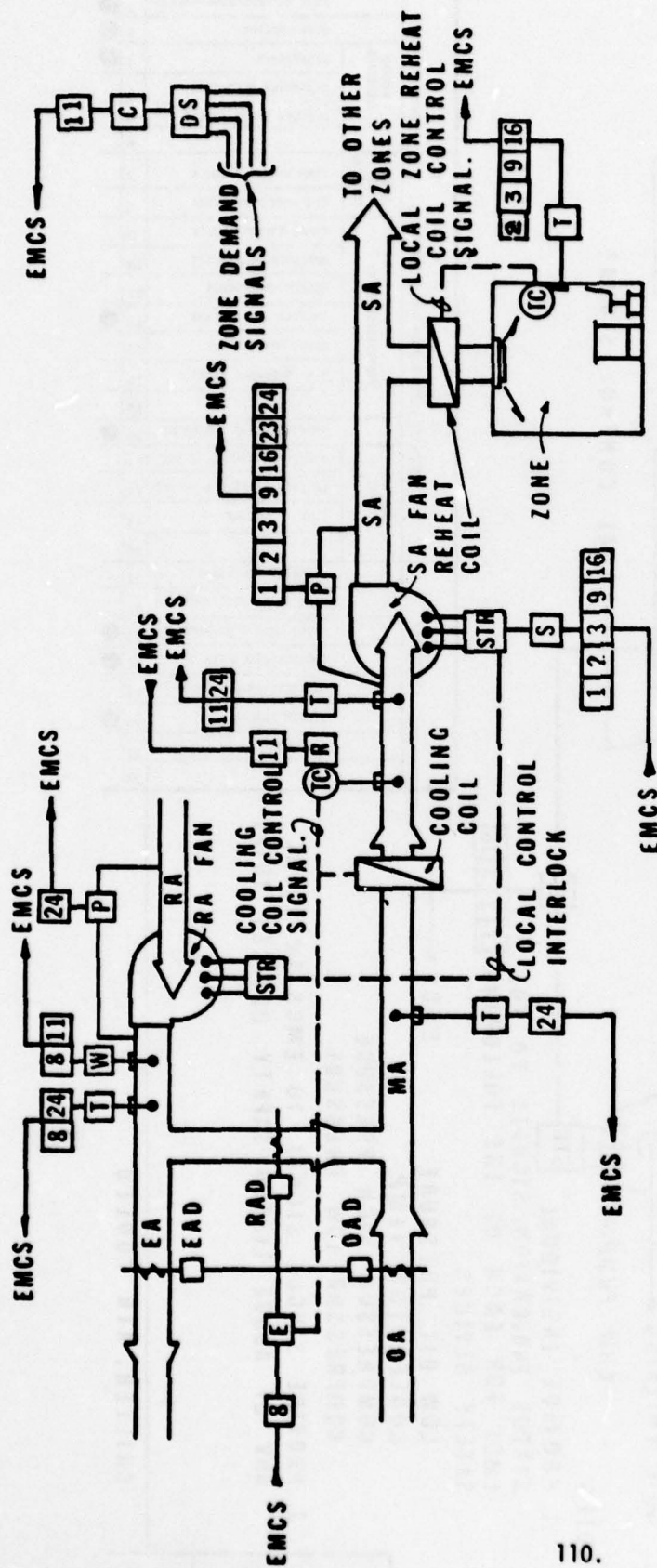
EQUIPMENT ON/OFF	EQUIPMENT OPTIMIZATION DURING OPERATION		TIME SCHEDULED OPERATION
	OUTSIDE AIR CONTROL	TEMPERATURE RESET	
START/STOP	WARM UP/NIGHT CYCLE	SPACE NIGHT SETBACK	1
GENERATOR OPERATION	ENTHALPY ECONOMIZER	HOT/COLD DECK RESET	2
CHILLER LIMIT ADJUST	REHEAT COIL RESET	CHILLED WATER RESET	3
	COND. WATER RESET	O.A. SCHEDULE RESET	4
			5
			6
			7
			8
			9
			10
			11
			12
			13
			14
			15
			16
			17
			18
			19
			20
			21
			22
			23
			24
			25
			26
			27
			28

DX UNIT, AIR COOLED



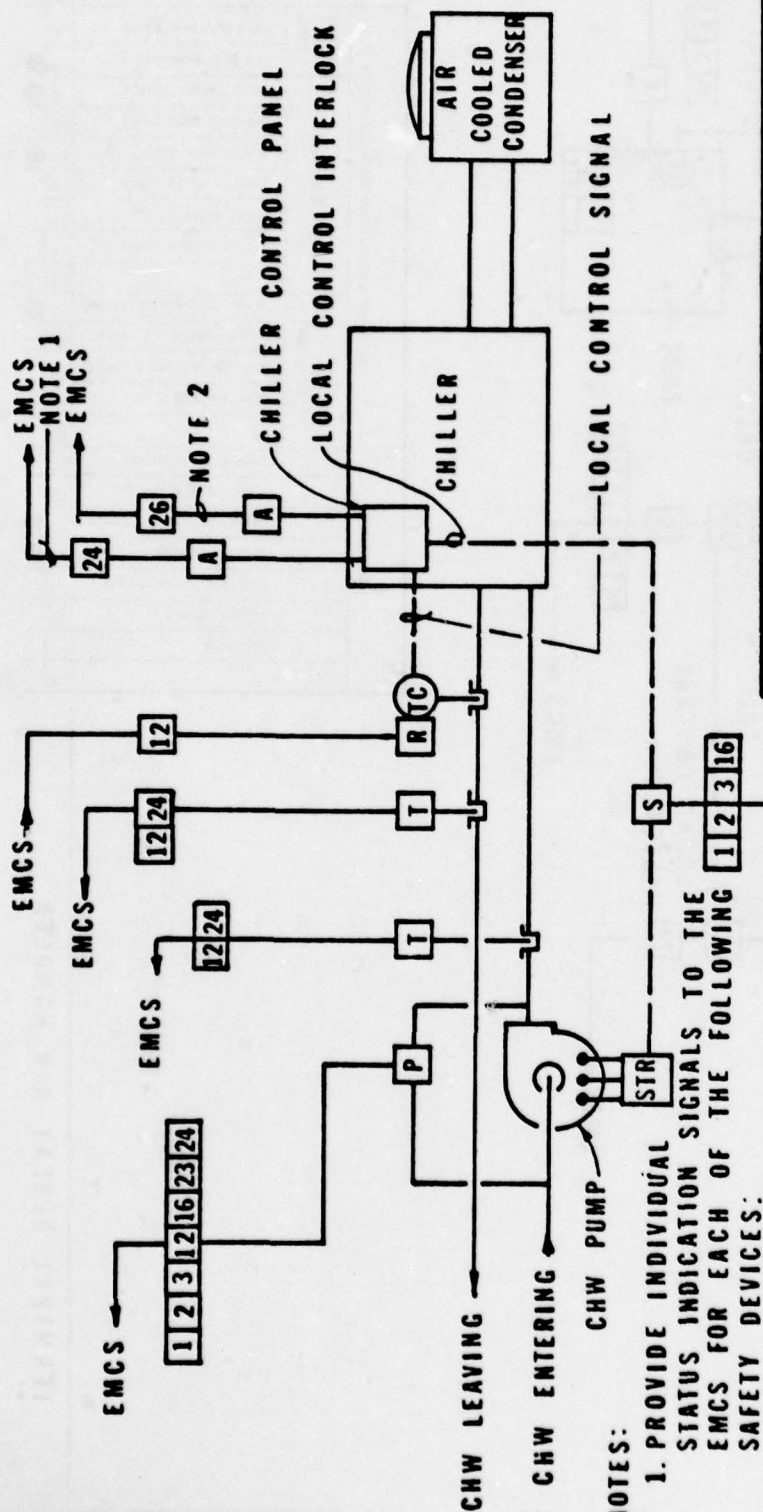
MONITORING	EQUIPMENT OPTIMIZATION DURING OPERATION		EQUIPMENT ON/OFF
	CENTRAL PLANT OPTIMIZATION	OUTSIDE AIR CONTROL	DE-AD LIFTING
SECURITY FUNCTIONS	21	WARM UP/NIGHT CYCLE	7
FIRE ALARM FUNCTIONS	22	ENTHALPY ECONOMIZER	8
MAINT. RUN TIME REPORTS	23	SPACE NIGHT SETBACK	9
TROUBLE DIAGNOSIS	24	HOT/COLD DECK RESET	10
CRITICAL AREAS ALARMS	25	REHEAT COIL RESET	11
SAFETY ALARMS	26	CHILLED WATER RESET	12
INTERCOM	27	COND. WATER RESET	13
	28	O.A. SCHEDULE RESET	14
			15
		START/STOP OPTIMIZATION	16
		BOILER PROFILE & SELECT	17
		CHILLER PROFILE & SELECT	18
		PUMP SELECTION	19
			20
			21
			22
			23
			24
			25
			26
			27
			28

SINGLE ZONE AIR HANDLER



EQUIPMENT 05/077	EQUIPMENT OPTIMIZATION DURING OPERATION		EQUIPMENT 05/077
	OUTSIDE AIR CONTROL	TEMPERATURE RESET	
EQUIPMENT 05/077	OUTSIDE AIR CONTROL	TEMPERATURE RESET	TIME SCHEDULED OPERATION
			DUTY CYCLING
			START/STOP
			GENERATOR OPERATION
EQUIPMENT 05/077	OUTSIDE AIR CONTROL	TEMPERATURE RESET	CHILLER LIMIT ADJUST
			WARM UP/NIGHT CYCLE
			ENTHALPY ECONOMIZER
			SPACE NIGHT SETBACK
EQUIPMENT 05/077	OUTSIDE AIR CONTROL	TEMPERATURE RESET	HOT/COLD DECK RESET
			REHEAT COIL RESET
			CHILLED WATER RESET
			COND. WATER RESET
EQUIPMENT 05/077	OUTSIDE AIR CONTROL	TEMPERATURE RESET	O.A. SCHEDULE RESET
			START/STOP OPTIMIZATION
			BOILER PROFILE & SELECT
			CHILLER PROFILE & SELECT
EQUIPMENT 05/077	OUTSIDE AIR CONTROL	TEMPERATURE RESET	PUMP SELECTION
			SECURITY FUNCTIONS
			FIRE ALARM FUNCTIONS
			MAINT. RUN TIME REPORTS
EQUIPMENT 05/077	OUTSIDE AIR CONTROL	TEMPERATURE RESET	TROUBLE DIAGNOSIS
			CRITICAL AREAS ALARMS
			SAFETY ALARMS
			INTERCOM

TERMINAL REHEAT AIR HANDLER



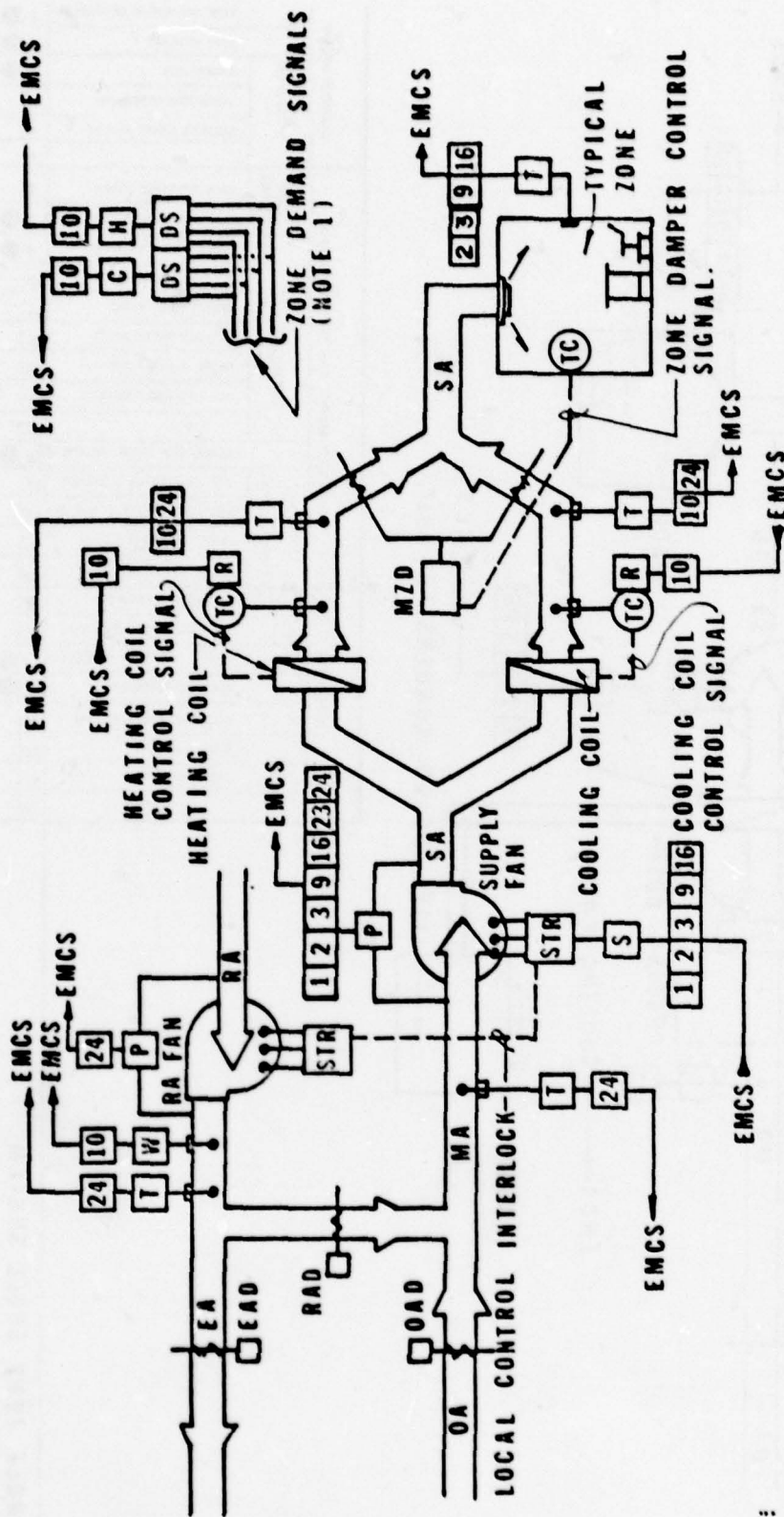
NOTES:

1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNALS TO THE EMCS FOR EACH OF THE FOLLOWING SAFETY DEVICES:

- LOW OIL PRESSURE
 - COOLER LOW TEMP.
 - COMPRESSOR HIGH PRESSURE
 - COMPRESSOR LOW PRESSURE
2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF ABOVE LISTED SAFETY DEVICES TRIPS

EQUIPMENT ON/OFF	EQUIPMENT OPTIMIZATION DURING OPERATION	MONITORING	EQUIPMENT ON/OFF	EQUIPMENT ON/OFF
EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	TIME SCHEDULED OPERATION
				DUTY CYCLING
				START/STOP
				GENERATOR OPERATION
				CHILLER LIMIT ADJUST
EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	CHILLER LIMIT ADJUST
				WARM UP/NIGHT CYCLER
				ENTHALPY ECONOMIZER
				SPACE NIGHT SETBACK
				HOT/COLD DECK RESET
				REFRIG. COIL RESET
				CHILLED WATER RESET
				COND. WATER RESET
				O.A. SCHEDULE RESET
				START/STOP OPTIMIZATION
EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	START/STOP OPTIMIZATION
				BOILER PROFILE & SELECT
				CHILLER PROFILE & SELECT
				PUMP SELECTION
				SECURITY FUNCTIONS
				FIRE ALARM FUNCTIONS
				MAINT. RUN TIME REPORTS
				TROUBLE DIAGNOSIS
				CRITICAL AREAS ALARMS
				SAFETY ALARMS
EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	EQUIPMENT ON/OFF	INTERCOM

CHILLER, AIR COOLED



NOTES:

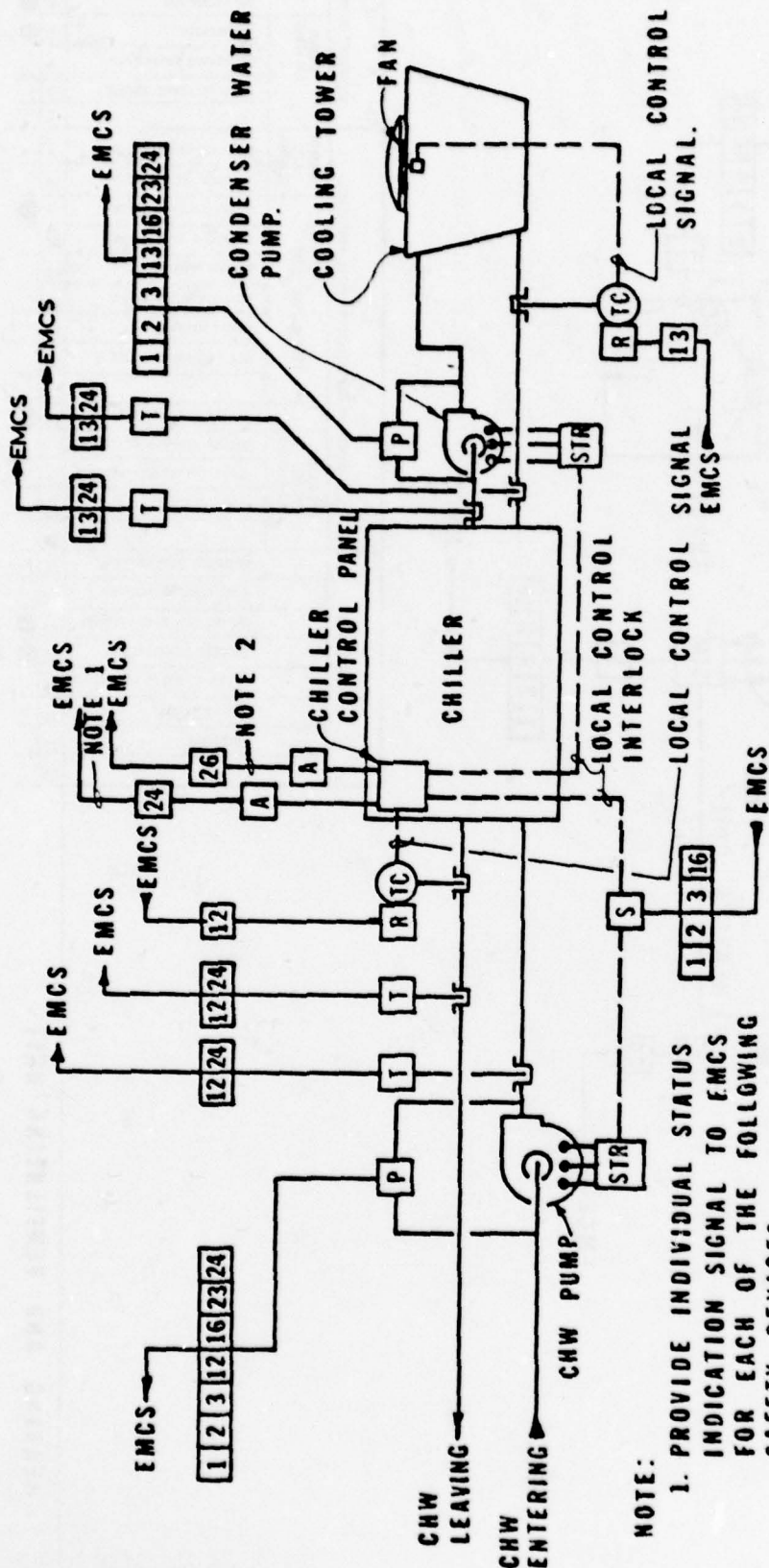
1. ZONE DEMAND SIGNALS SHALL INDICATE ZONE DAMPER POSITION FOR EACH ZONE. ZONE DAMPER CONTROL SIGNAL FROM ROOM THERMOSTAT MAY BE UTILIZED ONLY IF THAT SIGNAL IS CONTINUOUSLY PROPORTIONAL TO ZONE DEMAND.

MONITORING	EQUIPMENT OPTIMIZATION DURING OPERATION	EQUIPMENT ON/OFF	TIME SCHEDULED OPERATION	
MONITORING	EQUIPMENT OPTIMIZATION DURING OPERATION	EQUIPMENT ON/OFF	START/STOP	1
			GENERATOR OPERATION	2
			CHILLER LIMIT ADJUST	3
			WARM UP/NIGHT CYCLE	4
			ENTHALPY ECONOMIZER	5
			SPACE NIGHT SETBACK	6
			HOT/COLD DECK RESET	7
			REHEAT COIL RESET	8
			CHILLED WATER RESET	9
			COND. WATER RESET	10
			O.A. SCHEDULE RESET	11
			START/STOP OPTIMIZATION	12
			BOILER PROFILE & SELECT	13
			CHILLER PROFILE & SELECT	14
			PUMP SELECTION	15
MONITORING	EQUIPMENT OPTIMIZATION DURING OPERATION	EQUIPMENT ON/OFF	SECURITY FUNCTIONS	16
			FIRE ALARM FUNCTIONS	17
			MAINT. RUN TIME REPORTS	18
			TROUBLE DIAGNOSIS	19
			CRITICAL AREAS ALARMS	20
			SAFETY ALARMS	21
			INTERCOM	22
				23
				24
				25
				26
				27
				28

MULTI ZONE AIR HANDLER



SINGLE ZONE SPLIT SYSTEM



NOTE:

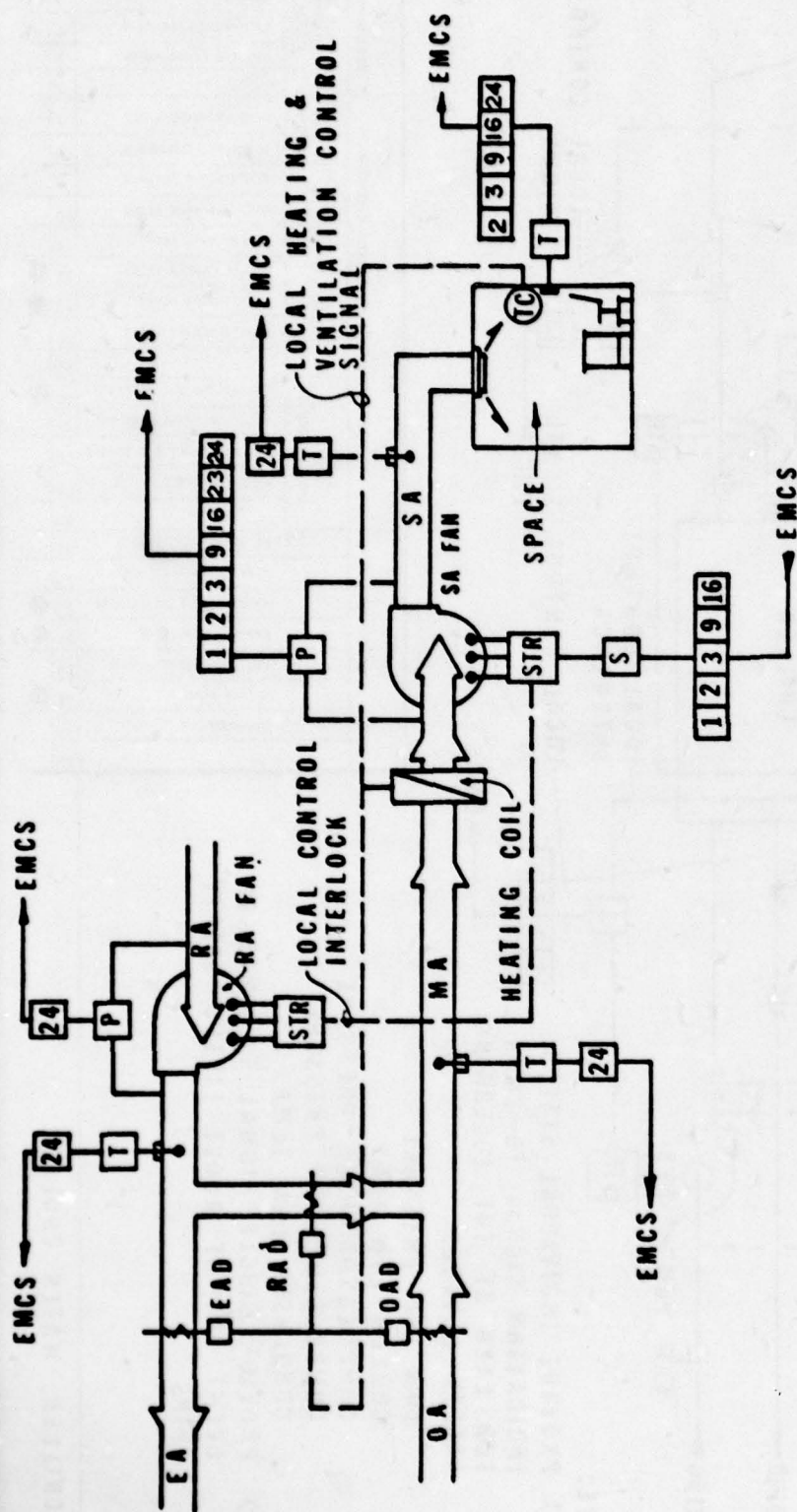
1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNAL TO EMCS FOR EACH OF THE FOLLOWING SAFETY DEVICES.

LOW OIL PRESSURE
COOLER LOW TEMP
COMPRESSOR HIGH PRESSURE
COMPRESSOR LOW PRESSURE
CONDENSER LOW TEMP

2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF ABOVE LISTED SAFETY TRIPS

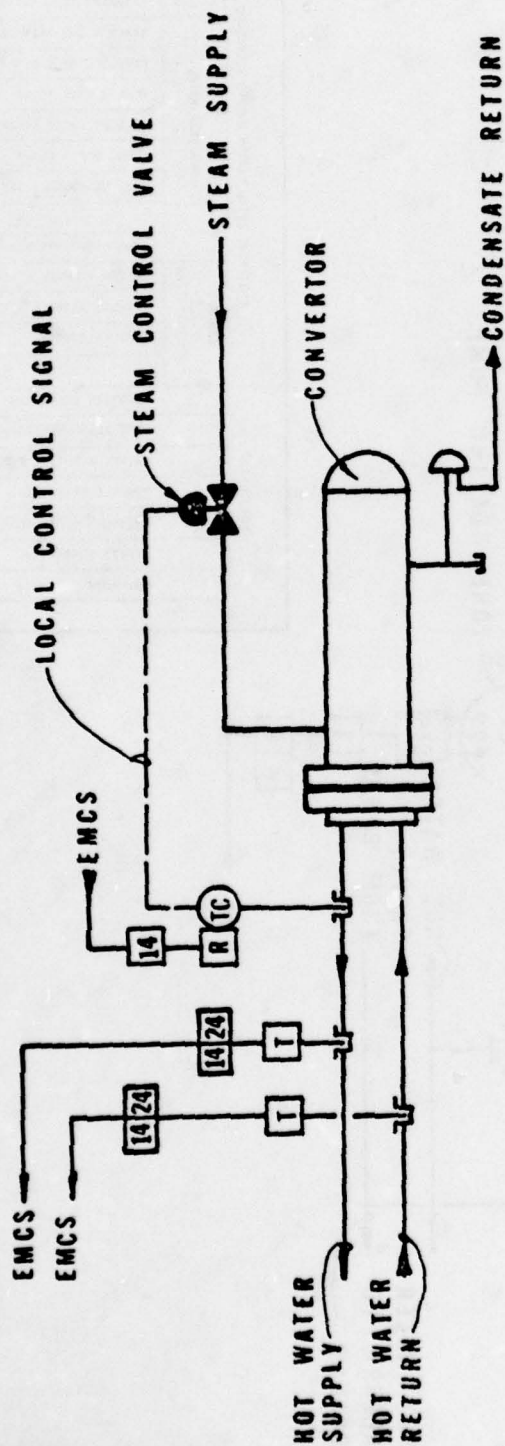
CHILLER, WATER COOLED

EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	TIME SCHEDULED OPERATION	1
		DUTY CYCLING	2
		START/STOP	3
		GENERATOR OPERATION	4
		CHILLER LIMIT ADJUST	5
	TEMPERATURE RESET		6
		WARM UP/NIGHT CYCLE	7
		ENTHALPY ECONOMIZER	8
		SPACE NIGHT SETBACK	9
		HOT/COLD DECK RESET	10
REHEAT COIL RESET		11	
CHILLED WATER RESET		12	
CENTRAL PLANT OPTIMIZATION	COND. WATER RESET	13	
	O.A. SCHEDULE RESET	14	
		15	
	START/STOP OPTIMIZATION	16	
	BOILER PROFILE & SELECT	17	
MONITORING	CHILLER PROFILE & SELECT	18	
	PUMP SELECTION	19	
		20	
	SECURITY FUNCTIONS	21	
	FIRE ALARM FUNCTIONS	22	
	MAINT. RUN TIME REPORTS	23	
	TROUBLE DIAGNOSIS	24	
	CRITICAL AREAS ALARMS	25	
	SAFETY ALARMS	26	
	INTERCOM	27	
	28		



EQUIPMENT CH/STP		EQUIPMENT OPTIMIZATION DURING OPERATION		MONITORING	
EQUIPMENT CH/STP	START/STOP	EQUIPMENT OPTIMIZATION DURING OPERATION	MONITORING	EQUIPMENT CH/STP	EQUIPMENT OPTIMIZATION DURING OPERATION
	GENERATOR OPERATION				
	CHILLER LIMIT ADJUST				
EQUIPMENT CH/STP	WARM UP/NIGHT CYCLE	EQUIPMENT OPTIMIZATION DURING OPERATION	MONITORING	EQUIPMENT CH/STP	EQUIPMENT OPTIMIZATION DURING OPERATION
	ENTHALPY ECONOMIZER				
	SPACE NIGHT DETRACK				
	HOT/COLD DECK RESET				
	REHEAT COIL RESET				
EQUIPMENT CH/STP	CHILLED WATER RESET	EQUIPMENT OPTIMIZATION DURING OPERATION	MONITORING	EQUIPMENT CH/STP	EQUIPMENT OPTIMIZATION DURING OPERATION
	COND. WATER RESET				
	O.A. SCHEDULE RESET				
EQUIPMENT CH/STP	START/STOP OPTIMIZATION	EQUIPMENT OPTIMIZATION DURING OPERATION	MONITORING	EQUIPMENT CH/STP	EQUIPMENT OPTIMIZATION DURING OPERATION
	BOILER PROFILE & SELECT				
	CHILLER PROFILE & SELECT				
	PUMP SELECTION				
EQUIPMENT CH/STP	SECURITY FUNCTIONS	EQUIPMENT OPTIMIZATION DURING OPERATION	MONITORING	EQUIPMENT CH/STP	EQUIPMENT OPTIMIZATION DURING OPERATION
	FIRE ALARM FUNCTIONS				
	MAINT. RUN TIME REPORTS				
	TROUBLE DIAGNOSIS				
	CRITICAL AREAS ALARMS				
EQUIPMENT CH/STP	SAFETY ALARMS	EQUIPMENT OPTIMIZATION DURING OPERATION	MONITORING	EQUIPMENT CH/STP	EQUIPMENT OPTIMIZATION DURING OPERATION
	INTERCOM				

HEATING AND VENTILATING UNIT

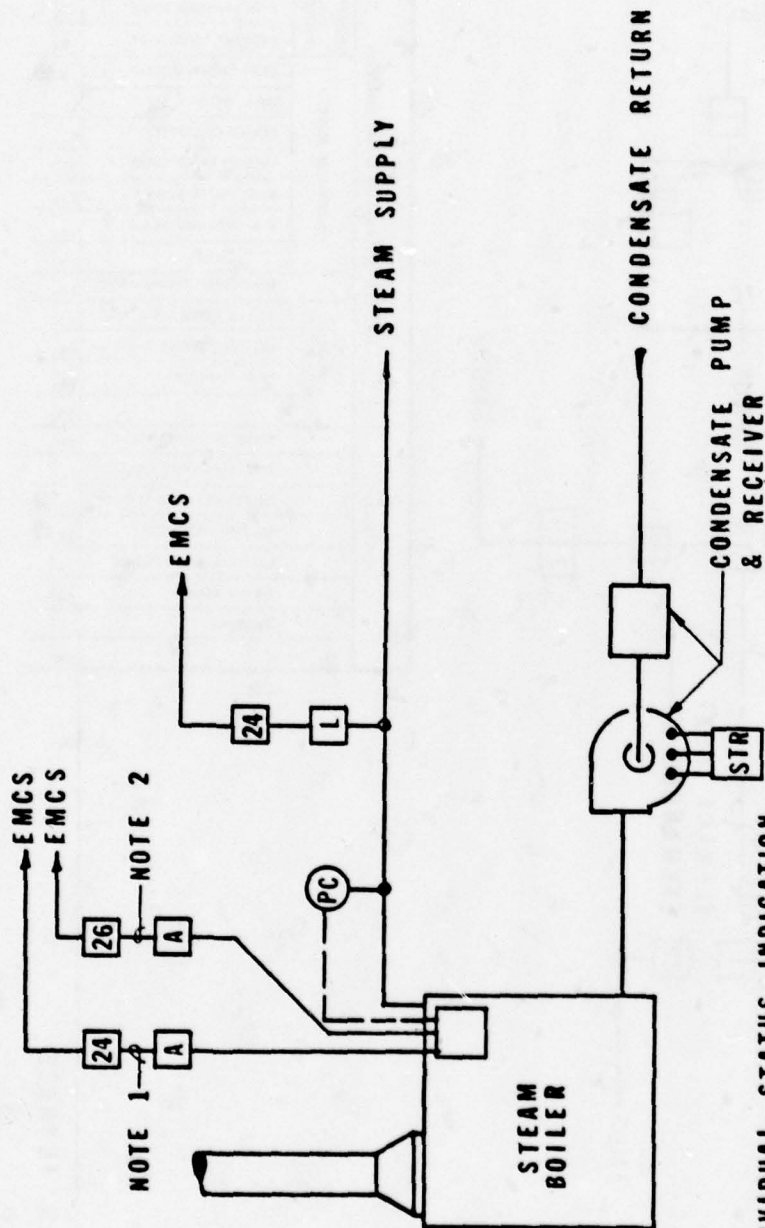


117.

EQUIPMENT ON/OFF	TIME SCHEDULED OPERATION		1	
	DUTY CYCLING		2	
	DEMAND LIMITING	START/STOP	3	
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
		6		
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
	CENTRAL PLANT OPTIMIZATION	START/STOP OPTIMIZATION	16	
		BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
	MONITORING		SECURITY FUNCTIONS	21
			FIRE ALARM FUNCTIONS	22
		MAINT. RUN TIME REPORTS	23	
		TROUBLE DIAGNOSIS	24	
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

HOT WATER CONVERTOR

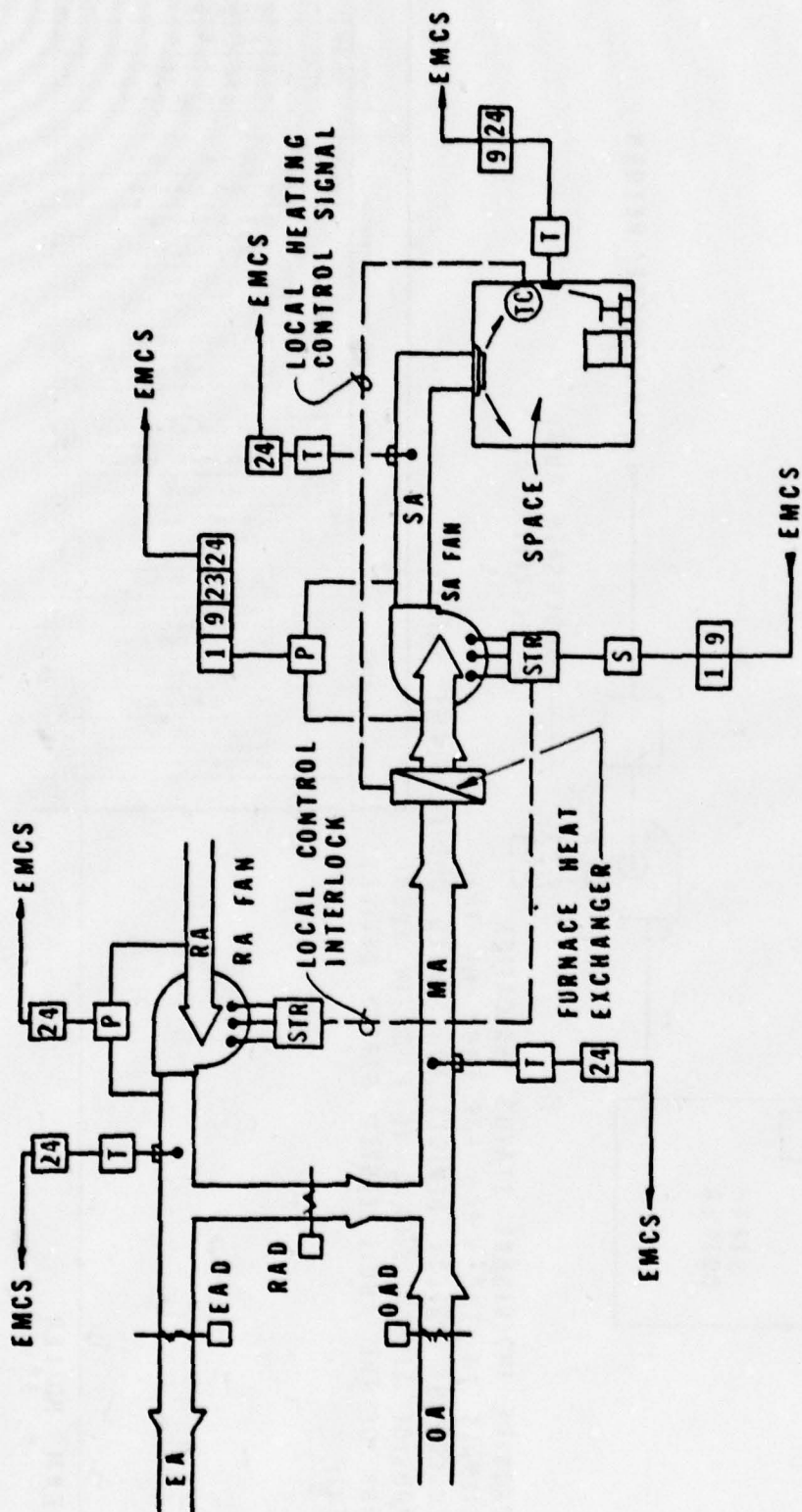
SCHEMATIC S-11



- NOTES:**
1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNALS TO THE EMCS FOR EACH OF THE FOLLOWING SAFETY DEVICES: LOW WATER CUTOFF, FLAME SAFETY.
 2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF THE ABOVE LISTED SAFETY DEVICES TRIP.

MONITORING		EQUIPMENT OPTIMIZATION DURING OPERATION		EQUIPMENT ON/OFF	
		TEMPERATURE RESET	OUTSIDE AIR CONTROL	STANDARD LIMITING	TIME SCHEDULED OPERATION
					DUTY CYCLING
					START/STOP
					GENERATOR OPERATION
		START/STOP OPTIMIZATION			CHILLER LIMIT ADJUST
					WARN UP/NIGHT CYCLE
					ENTHALPY ECONOMIZER
					SPACE NIGHT SETBACK
					HOT/COLD DECK RESET
					REHEAT COIL RESET
					CHILLED WATER RESET
		CENTRAL PLANT OPTIMIZATION			COND. WATER RESET
					O.A. SCHEDULE RESET
		SECURITY FUNCTIONS			
		FIRE ALARM FUNCTIONS			
		MAINT. RUN TIME REPORTS			
		TROUBLE DIAGNOSIS			
		CRITICAL AREAS ALARMS			
		SAFETY ALARMS			
		INTERCOM			

STEAM BOILER

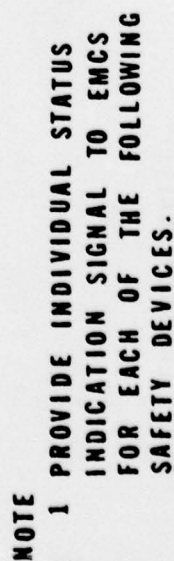


121.

EQUIPMENT ON/OFF	DEMAND LOADING	TIME SCHEDULED OPERATION	
		DUTY CYCLING	1
		START/STOP	2
		GENERATOR OPERATION	3
		CHILLER LIMIT ADJUST	4
			5
			6
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7
		ENTHALPY ECONOMIZER	8
		SPACE HEAT SYSTEM	9
		HOT/COLD DECK RESET	10
		REHEAT COIL RESET	11
	TEMPERATURE RESET	CHILLED WATER RESET	12
		COND. WATER RESET	13
		O.A. SCHEDULE RESET	14
			15
			16
	CENTRAL PLANT OPTIMIZATION	START/STOP OPTIMIZATION	17
		BOILER PROFILE A SELECT	18
		CHILLER PROFILE A SELECT	19
		PUMP SELECTION	20
			21
MONITORING		SECURITY FUNCTIONS	22
		FIRE ALARM FUNCTIONS	23
		MAINT. RUN TIME REPORTS	24
		TROUBLE DIAGNOSIS	25
		CRITICAL AREAS ALARMS	26
		SAFETY ALARMS	27
		INTERCOM	28
			29

DIRECT FIRED FURNACE

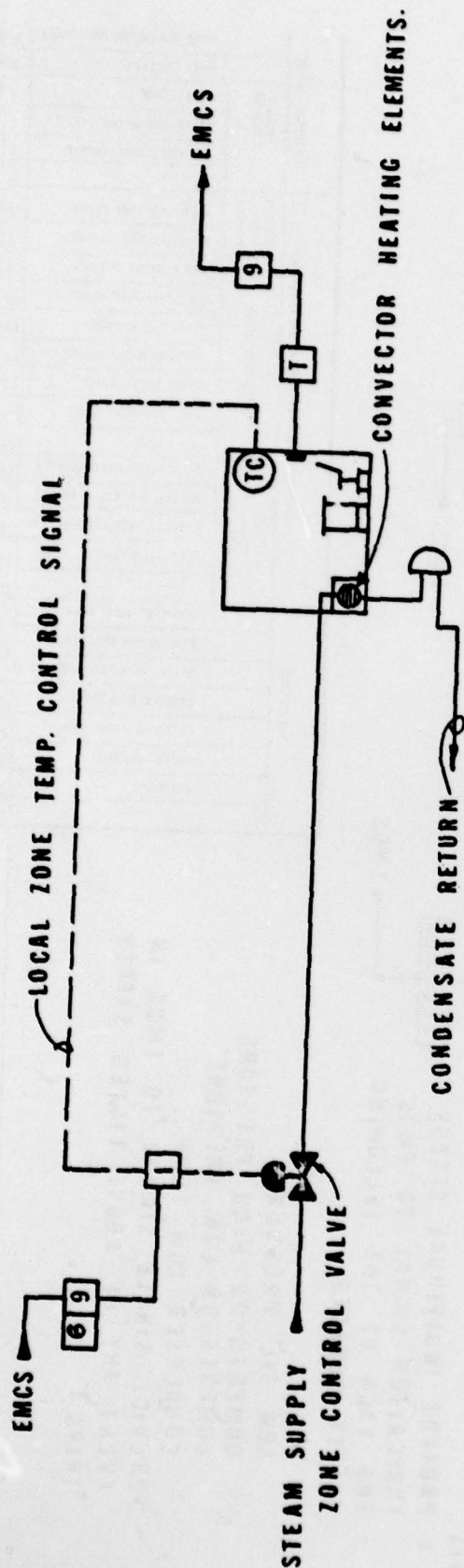
SCHEMATIC S-15



LOW OIL PRESSURE
COMPRESSOR HIGH PRESSURE
COMPRESSOR LOW PRESSURE
CONDENSER LOW TEMP.

2. PROVIDE SINGLE SIGNAL TO EMCS IN
EVENT ANY OF ABOVE LISTED SAFETY
TRIPS

OX UNIT, WATER COOLED



EQUIPMENT ON/OFF	TIME SCHEDULED OPERATION		
	EQUIPMENT	FUNCTION	
		W/IT CYCLING	1
		START/STOP	2
		GENERATOR OPERATION	3
		CHILLER LIMIT ADJUST	4
		O.A. LIMIT SHUTOFF	5
			6
		WARM UP/NIGHT CYCLE	7
		ENTHALPY ECONOMIZER	8
		SPACE NIGHT SETBACK	9
		HOT/COLD DECK RESET	10
		REHEAT COIL RESET	11
		CHILLED WATER RESET	12
		COND. WATER RESET	13
		O.A. SCHEDULE RESET	14
			15
		START/STOP OPTIMIZATION	16
		BOILER PROFILE & SELECT	17
		CHILLER PROFILE & SELECT	18
		PUMP SELECTION	19
			20
		SECURITY FUNCTIONS	21
		FIRE ALARM FUNCTIONS	22
		MAINT. RUN TIME REPORTS	23
		TROUBLE DIAGNOSIS	24
		CRITICAL AREAS ALARMS	25
		SAFETY ALARMS	26
		INTERCOM	27
			28

STEAM CONVECTOR HEATING SYSTEM

SCHEMATIC S-17

APPENDIX C - SAVINGS ANALYSIS DISCUSSION

FUNCTION: TIME SCHEDULED OPERATION

Simulate building loads and system operation using computerized energy analysis program. In initial run assume that systems run 24 hr/day, 7 day/week. In second run assume that systems run only during occupied hours plus one hour in the morning for warm up or cool down. Do not include fan KW in computer runs so that results are representative only of heating and cooling energy reduction. This heating and cooling energy savings can then be proportioned on a per cfm basis to other similar systems. Fan (or other auxiliaries) energy savings should then be added by multiplying the KW by the number of hours of shutdown for the system. Thus:

Cooling Savings = Difference in electrical consumption
of computer analysis runs.

Heating Savings = difference in heating consumption of
computer analysis runs.

Auxiliary Savings = $HP \times L \times KW/HP \times (8760 - H) \times C$

Where

HP = total fan motor nameplate horsepower

L = load factor

KW/HP = 0.746

H = number of hours of system operation

C = control efficiency factor

If the air handler is presently operating around the clock the above calculated savings may be used directly. If however the unit is currently started and stopped by a time switch, full credit can not be taken for the above savings for the EMCS. Determining what savings may be attributed to the EMCS becomes a function of the reliability of the time switch system. Time switches can be effective devices for the reduction of energy consumption, however, they have several disadvantages. They do not take into account holiday operation, seasonal changes, or daily weather variations. They are also easily tampered with, bypassed, or overridden. The pins which activate actions may slide, thus causing system operation and energy consumption at unnecessary times. They must be checked often to insure proper operation and must be reset manually everytime a power outage occurs for any appreciable time period. The EMCS is capable of performing the same operations as the time switches but without most of the difficulties described, since it is not within the reach of tampering, and system operations are monitored constantly by the console operator.

An exact method of analyzing the energy savings of an EMCS over a time switch system is not available. The survey of buildings indicates that some buildings with time switches are operating properly while others have been overridden or set improperly. With time clocks, a system that is operating properly one day may be operating improperly the next day. This is not true with the EMCS since modifications to operations must be made by the EMCS

operators. For these reasons, the EMCS savings over time switches will be estimated by multiplying an efficiency factor times the heating, cooling, and fan savings estimated above. The efficiency factor will be assumed to equal 0.3 in analysis in this report.

FUNCTION: DUTY CYCLING

Assume the system may be shut down for an average of 10 minutes per hour. The savings resulting from this function are fan energy and outside air heating and cooling energy. Outside air loads are difficult to determine since they actually depend on space load conditions. If there is a net cooling load in the space, and the outside air is below 75°F, the outside air actually reduces energy consumption. Also actual outside air quantities may be very different from design quantities, with no practical means of determining what the actual quantity is. Therefore outside air load savings will be ignored in duty cycling analysis.

$$SKWH = HP \times L \times 10/60 \times H \times KW/HP$$

Where

HP = total motor nameplate horsepower

10/60 = fraction of time system is shut down

H = required annual hours of system operation

L = load factor

KW/HP = 0.746

FUNCTION: DEMAND LIMITING START/STOP

Assume that system can be shed 25% of time under peak load conditions.

$$S = HP \times L \times KW/HP \times 0.25 \times M$$

Where

HP = total motor nameplate horsepower of all motors in system

L = load factor

KW/HP = 0.746

M = number of months per year system operates

FUNCTION: START/STOP OPTIMIZATION

Assume an average of 1/2 hour of fan operation per occupied day may be saved by this function. Assume no net heating or cooling energy is saved.

$$S = HP \times L \times KW/HP \times 0.5 \times OD$$

Where

HP = Total fan motor nameplate horsepower

L = load factor

KW/HP = 0.746

OD = number of occupied days per year

FUNCTION: OUTSIDE AIR LIMIT SHUTOFF

Savings are derived from reduced hours of operation of auxiliary equipment and reduction of system losses (heat transfer thru pipe walls, leaking steam traps, etc.). Whenever the system loss savings can be identified they should be included in the analysis, however, generally it is not possible to reasonably estimate what those losses are. Auxiliary savings are derived from the shutting off of pumps, fans, etc. Whenever the outside temperature crosses limits which, according to the time of year, indicate the heating or cooling media which those auxiliaries are moving is not required, the auxiliaries may be shut down. Auxiliary savings are thus:

$$SKWH = HP \times L \times KW/HP \times (HS + HW)$$

Where

HP = nameplate HP of constant loads

L = load factor

KW/HP = 0.746

HS = hours in summer outside temperature is below summer limit

HW = hours in winter outside temperature is above winter limit

FUNCTION: MAINTENANCE RUN TIME

By scheduling maintenance based on actual operation, assume the EMCS is able to save one man-visit per year to the system being monitored by the EMCS. Assume this man-visit is 2 hours in duration.

$$S = 2 \text{ man hours}$$

FUNCTION: ENTHALPY ECONOMIZER

Simulate building loads and enthalpy economizer operation with computerized building energy analysis program. In initial run assume that no economizer is operable, in second run simulate savings from conventional dry bulb economizer changeover, and in third run simulate savings from enthalpy economizer operation. All runs should be made assuming the system is operating the minimum number of hours necessary. Savings may be proportioned for similar systems on a per cfm basis.

FUNCTION: HOT/COLD DECK RESET

Simulate system operation with computerized energy analysis program. Program used should have simulation routines necessary to select the zones with the greatest demand and then calculate the necessary hot/cold deck leaving temperatures. In order to approximate the savings from this function, run the program once using constant deck setpoint temperatures and then a second time simulating variable deck temperature based on a discriminator control scheme.

FUNCTION: CHILLED WATER RESET

Assume approximately 1.5% efficiency increase may be obtained by increasing the average chilled water temperature 1°F. Assume the EMCS is capable of obtaining an average increase of 2°F. in chilled water temperature, thus a resultant savings of 3% of compressor and cooling tower fan energy should be realized. To conservatively approximate these savings, assume a loading of 1000 equivalent full load hours. Also assume an average consumption of 1 KWH/ton-hour. Savings resulting are:

$$S = T \times 1000 \text{ hrs.} \times 1 \text{ KWH/ton-hr} \times 0.03$$

Where

T = chiller capacity, tons

FUNCTION: CONDENSER WATER RESET

Assume approximately 1.5% efficiency increase may be obtained by decreasing the average condenser water temperature 1°F. Assume the EMCS is capable of obtaining an average decrease of 3°F. in condenser water temperature, thus a resultant savings of 4.5% of compressor energy should be realized. To conservatively approximate these savings, assume a loading of 1000 equivalent full load hours. Also assume an average consumption of 1 KWH/ton-hr. Savings resultings are:

$$S = T \times 1000 \text{ hrs} \times 1 \text{ KWH/ton-hr} \times 0.045$$

Where

T = chiller capacity, tons

FUNCTION: O.A. SCHEDULE RESET

Boiler temperature reset saves by reducing heat losses through the heating system and flue gases and by providing more exact control at the end use point. This last item provides savings by reducing overheating of spaces at less than maximum loads due to control valve insensitivity in those operating ranges. No exact means of quantifying these savings is known, however experience indicates these savings should be a function of the annual equivalent full load hours of boiler operation and the total capacity of the boiler.

$$S = EFLH \times PECD \times I$$

Where

S = annual savings, Therms

H = annual equivalent full load hours for boiler

PECD = efficiency increase

I = maximum heat transfer capacity of device, therms

FUNCTION: SAFETY ALARM

Assume total of 2 hours saved per year of occupant and maintenance personnel time in conveying alarm information.

$$S = 2 \text{ man-hours}$$

APPENDIX D - ANALYSIS FORMS

SURVEY AND BUILDING DESCRIPTION FORM

Building Number: _____ Usage: _____

Gross Area Sq. Ft.: _____ No. Floors: _____

Age of Building: _____ Type Construction: _____

Approx. Floor to Floor Height: _____

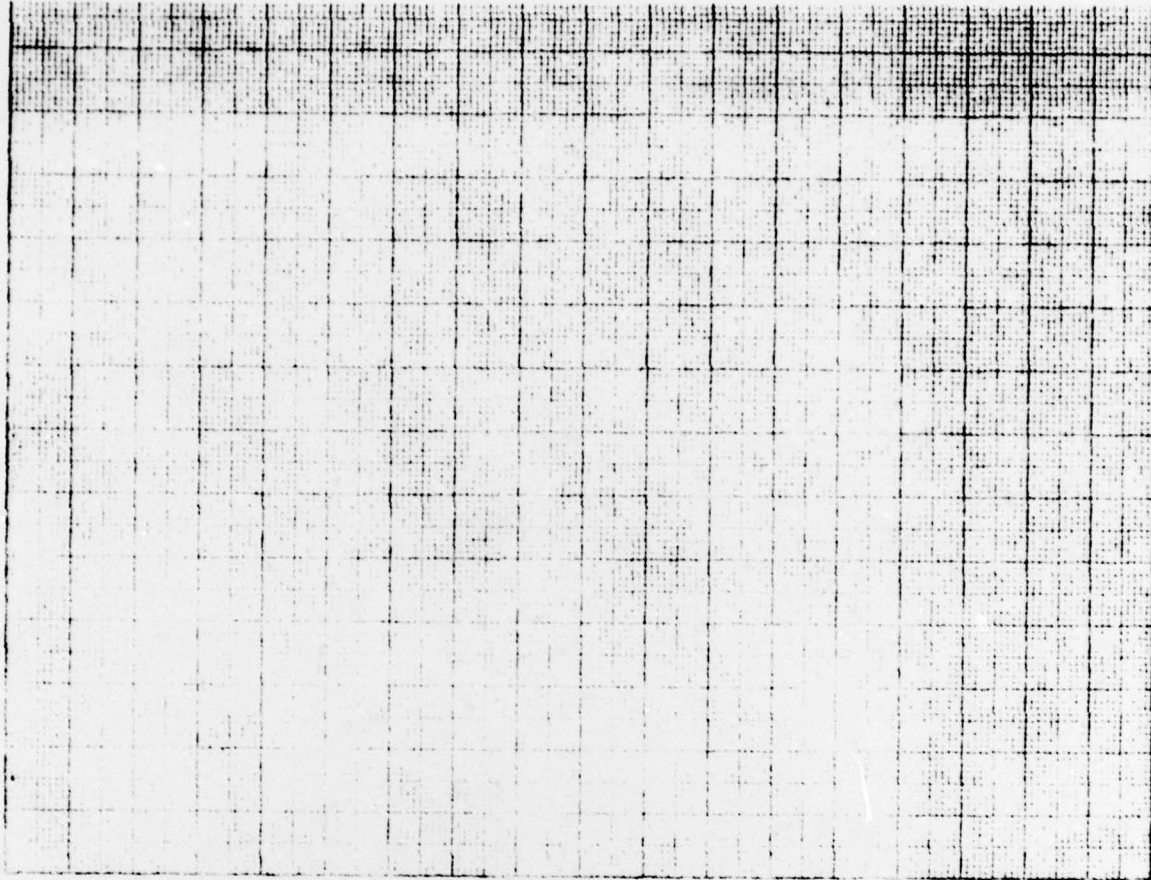
% Glass in Exterior Wall: _____

Glass Shading: External _____ Internal _____

"U" Factor: Roof _____ Wall _____ Glass _____

Critical Areas: _____

Notes: _____



PRIMARY SYSTEMS

SECONDARY SYSTEMS

Sys #	Sys #	Sys #	Sys #
<p>Type: (HW) (STM) (W/C) (W/C) (W/C) (W/C)</p> <p>Boiler (A/C) (A/C) (A/C) (A/C)</p> <p>Chiller (A/C) (A/C) (A/C) (A/C)</p> <p>DX Unit (A/C) (A/C) (A/C) (A/C)</p> <p>Central (STM) (STM) (STM) (STM)</p> <p>Other: (W/C) (W/C) (W/C) (W/C)</p> <p>Capacity: BTU/HR.</p> <p>Pump HP: _____</p> <p>Comp HP: _____</p> <p>Fan HP: _____</p> <p>Other HP: _____</p> <p>Operation (Annual)</p> <p>Year Round _____</p> <p>Summer Only _____</p> <p>Winter Only _____</p> <p>Other: _____</p> <p>Operation (Daily)</p> <p>1 Shift _____</p> <p>2 Shift _____</p> <p>3 Shift _____</p> <p>Other: _____</p> <p>Existing Controls:</p> <p>Time Clock _____</p> <p>O.A. Reset _____</p> <p>Other: _____</p> <p>Notes: _____</p>	<p>Type: (HW) (STM) (W/C) (W/C) (W/C) (W/C)</p> <p>Boiler (A/C) (A/C) (A/C) (A/C)</p> <p>Chiller (A/C) (A/C) (A/C) (A/C)</p> <p>DX Unit (A/C) (A/C) (A/C) (A/C)</p> <p>Central (STM) (STM) (STM) (STM)</p> <p>Other: (W/C) (W/C) (W/C) (W/C)</p> <p>Capacity: BTU/HR.</p> <p>Pump HP: _____</p> <p>Comp HP: _____</p> <p>Fan HP: _____</p> <p>Other HP: _____</p> <p>Operation (Annual)</p> <p>Year Round _____</p> <p>Summer Only _____</p> <p>Winter Only _____</p> <p>Other: _____</p> <p>Operation (Daily)</p> <p>1 Shift _____</p> <p>2 Shift _____</p> <p>3 Shift _____</p> <p>Other: _____</p> <p>Existing Controls:</p> <p>Time Clock _____</p> <p>O.A. Reset _____</p> <p>Other: _____</p> <p>Notes: _____</p>	<p>Type: (HW) (STM) (W/C) (W/C) (W/C) (W/C)</p> <p>Boiler (A/C) (A/C) (A/C) (A/C)</p> <p>Chiller (A/C) (A/C) (A/C) (A/C)</p> <p>DX Unit (A/C) (A/C) (A/C) (A/C)</p> <p>Central (STM) (STM) (STM) (STM)</p> <p>Other: (W/C) (W/C) (W/C) (W/C)</p> <p>Capacity: BTU/HR.</p> <p>Pump HP: _____</p> <p>Comp HP: _____</p> <p>Fan HP: _____</p> <p>Other HP: _____</p> <p>Operation (Annual)</p> <p>Year Round _____</p> <p>Summer Only _____</p> <p>Winter Only _____</p> <p>Other: _____</p> <p>Operation (Daily)</p> <p>1 Shift _____</p> <p>2 Shift _____</p> <p>3 Shift _____</p> <p>Other: _____</p> <p>Existing Controls:</p> <p>Time Clock _____</p> <p>O.A. Reset _____</p> <p>Other: _____</p> <p>Notes: _____</p>	<p>Type: (SZ) (TR) (HW) (W/C) (W/C) (W/C)</p> <p>Unit Htr. (A/C) (A/C) (A/C) (A/C)</p> <p>Fan Coil (A/C) (A/C) (A/C) (A/C)</p> <p>Convactor (HW) (HW) (HW) (HW)</p> <p>Other: (W/C) (W/C) (W/C) (W/C)</p> <p>Capacity: BTU/HR.</p> <p>Pump HP: _____</p> <p>Comp HP: _____</p> <p>Fan HP: _____</p> <p>Other HP: _____</p> <p>Operation (Daily)</p> <p>1 Shift _____</p> <p>2 Shift _____</p> <p>3 Shift _____</p> <p>Other: _____</p> <p>Existing Controls:</p> <p>Time Clock _____</p> <p>Economizer _____</p> <p>Deck Reset _____</p> <p>Other: _____</p> <p>Notes: _____</p>

System Type

TOTALS FOR SYSTEM

BUILDING SAVINGS - COST SUMMARY

Building # _____

[illegible]

$$\text{ENERGY SAVINGS} = \frac{(\text{KWH} \times 11,600) + (\text{THERMS} \times 100,000)}{1,000,000 \text{ BTU/MBTU}} = \text{MBTU}$$

$$\text{\$ SAVINGS} = \left(\frac{\text{KW} \times \$}{\text{KW}} \right) + \left(\frac{\text{KWH} \times \$}{\text{KWH}} \right) + \left(\frac{\text{THERMS} \times \$}{\text{THERM}} \right) + \left(\frac{\text{MH} \times \$}{\text{MH}} \right) = \$$$

E/C RATIO = _____

PRIORITIZED BUILDING LIST

[illegible]

ECIP ECONOMIC ANALYSIS SUMMARY

ACTIVITY & LOCATION _____ P- _____

TITLE OF PROJECT _____ FY- _____

INVESTMENT

1. PROJECT COSTS (Economic life of _____ years)
 - a. Project cost escalated to end of program year.... \$ _____
 - b. Design costs not yet obligated \$ _____
 - c. Total Project Cost (a + b) \$ _____

SAVINGS

2. ANNUAL ELECTRICITY SAVINGS: KWH: _____
 - a. Equivalent energy: KWH x 0.0116 (MBTU's: \$ _____)
 - b. Cost per KWH at end of program year \$ _____
 - c. First year annual dollar savings (KWH x b) \$ _____
 - d. Differential escalation present worth factor
 - e. Discounted savings (c x d) \$ _____
3. ANNUAL ENERGY SAVINGS (TYPE: _____ MBTU's: _____)
 - a. Cost per MBTU at end of program year \$ _____
 - b. First year annual dollar savings \$ _____
 - c. Differential escalation present worth factor
 - d. Discounted savings (b x c) \$ _____
4. ANNUAL ENERGY SAVINGS (TYPE: _____ MBTU's: _____)
 - a. Cost per MBTU at end of program year \$ _____
 - b. First year annual dollar savings \$ _____
 - c. Differential escalation present worth factor
 - d. Discounted savings (b x c) \$ _____
5. ANNUAL OTHER-THAN-ENERGY SAVINGS (OR COSTS)
 - a. Labor \$ _____
 - b. Material & Other \$ _____
 - c. Total (a + b) \$ _____
 - d. 10% Discount Factor \$ _____
 - e. Discounted Other-than-energy savings (or costs) . \$ _____
6. TOTAL FIRST YEAR ANNUAL SAVINGS (2c + 3b + 4b + 5c) .. \$ _____
7. TOTAL DISCOUNTED SAVINGS (2e + 3d + 4d + 5e) \$ _____

COST ESCALATION

Current	Elec	\$	x	x	x	x	=	\$
rates	Oil	\$	x	x	x	x	=	\$
as of	Gas	\$	x	x	x	x	=	\$
		\$	x	x	x	x	=	\$

RATIOS

8. DISCOUNTED SAVINGS/INVESTMENT RATIO (Line 7 ÷ 1c)
9. TOTAL MBTU SAVINGS _____ ÷ (Line 1a ÷ 1000)
10. SIMPLE PAYBACK PERIOD (1a ÷ Line 6) YRS

NOTE: For ETAP projects use line 1c in lines 9 and 10 in lieu of 1a.